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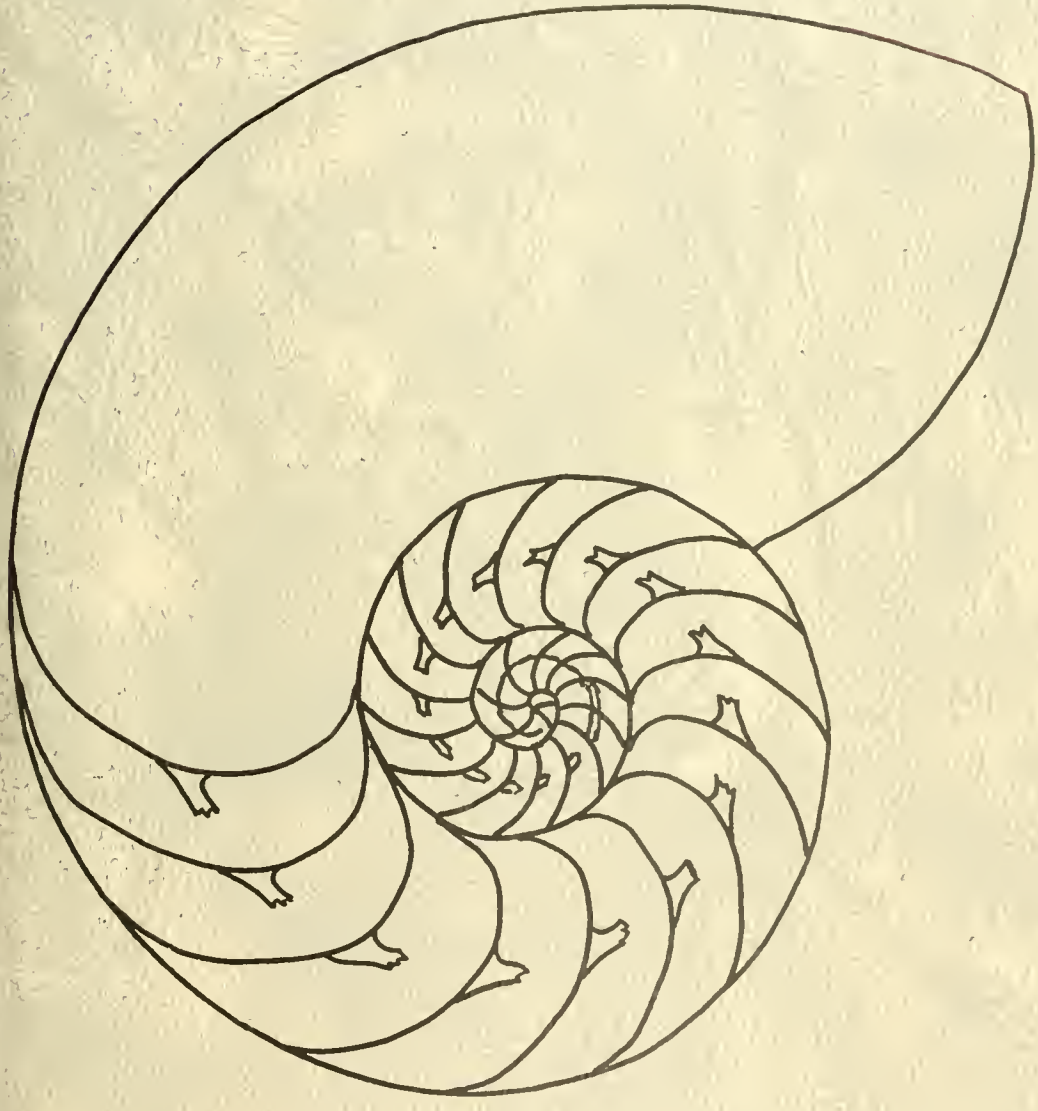

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PUBLICATIONS RECEIVED

Brown, David S. *Freshwater Snails of Africa and their Medical Importance.* 487 pp., 153 pls. 1980. Taylor and Francis, Ltd., London. Distributed in the Americas by American Malacologists, Inc., P. O. Box 2255, Melbourne, FL 32901. Hardback, £25 in England, $55.00 U.S. Extensive coverage.

Warén, Anders. 1980. Marine Mollusca Described by John Gwyn Jeffreys, with the Location of the Type Material. Special Publication, no. 1, *Conch. Soc. Great Britain and Ireland,* 66 pp., 8 pls. $12.50. A very valuable taxonomic tool, including a biography, bibliography and lists of Jeffreys' new names.

Nautilus macromphalus in Captivity. 1980. Edited by T. Hamada, I. Obata and T. Okutani. Takai University Press, Tokyo. 80 pp., 55 color pls., hardback. $33.00. A detailed account by 17 Japanese scientists on rearing, behavior, biometrics, distribution and biology of the New Caledonia Nautilus.

Petuch, Edward J. 1979. Twelve New Indo-Pacific Gastropods. *Nemouria,* no. 23, pp. 1–21. New taxa include *Guildfordia, Zelippistes, Pseudocypraea, Morum, Axymene, Oliva, Agatrix* and 5 *Conus.* Several seem to be subjective synonyms.

Cernohorsky, W. O. 1980. Revision of the Australian and New Zealand Tertiary and Recent Temperate Species of the Family Costellariidae. *Records Auckland Inst. and Mus.* vol. 16, pp. 109–169.

Davidson, Alan. 1979. *North Atlantic Seafood.* 512 pp. Numerous text drawings. Viking Press, N. Y. $15.95. Hardback. Excellent book of recipes and natural history of edible fish (with 30 pages on mollusks). Excellent cookery bibliography.

Arakawa, K. Y. (translated by R. B. Gillmor). 1980. Prevention and Removal of Fouling on Cultured Oysters; A Handbook for Growers. *Maine Sea Grant Technical Report* 56, 38 pp. Ira C. Darling Center, Walpole, ME 04573.

Boletin del Grupo de Estudios Malacol, "Arango". June 1980. No. 2, 19 pp. Biography of Rafael Arango; List of mollusca from Isla de La Juventud, Cuba.

Solem, Alan. 1979. Camaenid Land Snails from Western and Central Australia. Pt. 1, Taxa with Trans-Australian Distribution. *Records Western Australian Mus.,* Suppl. no. 10, 142 pp., 35 figs. A thorough study of 10 genera, including the new *Melostrachia,* and 7 new species.

_____ 1979. Some Mollusks from Afghanistan. *Fieldiana: Zoology* (new series), no. 1, 89 pp., 32 figs. 37 taxa, including a new *Pupilla* are reported upon.

Lan, T. C. 1980. *Rare Shells of Taiwan in Color.* Privately published, T. C. Lan, 40 Lane 105, Liao-ning St., Taipei, Taiwan. 144 pp., illus. in color. This is a magnificently illustrated book of 77 rare and uncommon marine mollusks, with additional illustrations of some cameos and ancient forms of Chinese shell money. The book contains species not likely to be found in the average museum or private collection. $18.00.

Walls, Jerry G. 1980. *Conchs, Tibias and Harps.* 191 pp., illus. in color. T. F. H. Publications, Neptune, NJ 07753. This is a useful and colorful guide to the Strombidae and Harpidae. Most of the information was evidently from out-of-print numbers of *Indo-Pacific Mollusca.* $9.95.

Johnson, Richard I. 1980. Zoography of North American Unionacea (Mollusca: Bivalvia) North of the Maximum Pleistocene Glaciation. *Bull. Mus. Comp. Zool.,* Harvard, vol. 149, no. 2, pp 189, 20 pls. An exhaustive and well-illustrated account of unionids that moved north as the Pleistocene glaciers receded. A complementary study of the fish hosts by an ichthyologist would be welcome.

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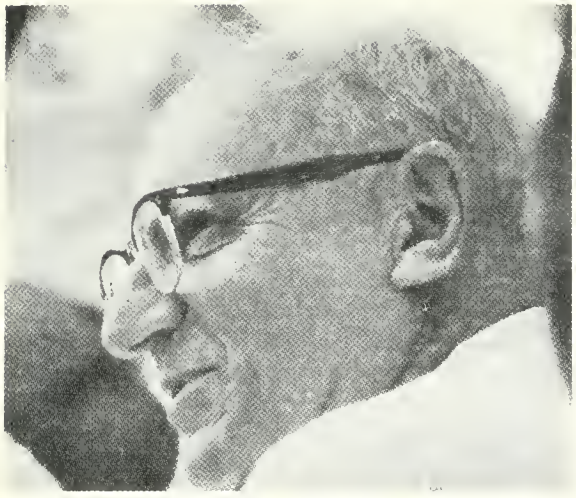
(signed) R. Tucker Abbott, Editor



Henryk Bronislaw Stenzel
(1899–1980)

Henryk Bronislaw Stenzel was born in Pabinanice, Poland, on 7 February 1899. When he was 23 years old he obtained the degree of Doctor of Philosophy in Geology from the University of Breslau, where he remained as assistant lecturer for two more years. In 1925 he joined the faculty of the Department of Geology at Texas Agricultural and Mechanical College (now Texas A & M University), where he taught for nine years, during which time he became a U.S. citizen. There the extensive array of fossil mollusks from the Stone City outcrop of middle Eocene age on the nearby Brazos river attracted his attention.

A firm believer in the maxim that the present is a key to the past, he augmented his observations on fossils by excursions into the study of living marine mollusks. Since the ones which interested him most were in remote areas of the world, he was chiefly limited to reviewing the literature. A master chapter on the *Living Nautilus* in the *Treatise on Invertebrate Paleontology* (1964) was one result. In this he recognized five living species, and presented a map showing where they had been found alive, as well as where their shells had drifted.

In 1934 he joined the Bureau of Economic Geology of the University of Texas at Austin. There his teaching was chiefly guiding the research of graduate students, but he spent much more time in fieldwork. His studies on the geology of various regions of eastern Texas were mostly published by the Bureau. His research interests turned to the systematics of oysters, which are abundant and diversified in the Cretaceous and Tertiary deposits of Texas.

Undaunted by the extreme variations in oysters, he first undertook the review of all generic names which had been proposed in the group, the determination of the essential characters of each genus on the basis of their type species, and thereby the elimination of superfluous names by detecting synonyms and homonyms. As with his study of *Nautilus*, this project went very slowly in a region where scientific libraries are limited in size.

After 20 years at the Bureau of Economic Geology and three years as Chairman of the Department of Geology of the University of Houston, he became a consulting geologist for the Shell Development Co., in Houston. In his ten years with this company he was able to devote more time to oyster systematics, and during that period he also participated at Rice University as a teacher of summer field courses on Gulf Coast geology.

In 1967 he moved to Baton Rouge, and as Visiting Professor of Geology at Louisiana State University, he was able to complete his study of oysters. This was published as a special volume of the *Treatise on Invertebrate Paleontology*. It undoubtedly has put the systematics of oysters on a firm foundation, far surpassing all the previous work on the subject.

In Baton Rouge he lived alone, having been widowed many years before, and his three daughters having married and moved to distant places. His health gradually deteriorated. Donating his library to Louisiana State University, he returned to Houston in 1977, where, following a long illness, he passed away on 5 September 1980. A member of numerous geological societies, he was past president of the Society of Economic Paleontology and Mineralogy (1949–1950) and of the Paleontological Society (1955–1956). He was a scholar and a gentleman with the grace and elegance of bygone generations, a pleasant companion and captivating racconteur of malacological vignettes. He is truly missed by his many friends.

–*Harold W. Harry*, 4612 Evergreen, Bellaire, Texas 77401.

ANATOMY AND SYSTEMATICS OF *GOURMYA GOURMYI* (PROSOBRANCHIA: CERITHIIDAE), A TETHYAN RELICT FROM THE SOUTHWEST PACIFIC

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ABSTRACT

Gourmya gourmyi *(Crosse, 1861) a Tethyan relict cerithiid snail, is the sole survivor of a long lineage that can be traced back to the Eocene of the Paris Basin. It is today restricted to subtidal coral reefs of island groups around New Caledonia where it lives at moderate depths on hard substratum, The shell is stocky and the siphonal canal is crossed over by the base of the outer shell lip giving the aperture a circular appearance. Ocelli are present on the inhalant siphon. These, a large esophageal gland, extensive gastric shield and the arrangement of the spermatophore chamber and seminal receptacle are unique anatomical features which establish* Gourmya *as a valid genus in the family Cerithiidae.*

Gourmya gourmyi (Crosse) is a relatively large cerithiid with an unusual shell morphology that lives on subtidal coral reefs in a restricted part of the tropical southwest Pacific. It is not well-known and is uncommon in most museum collections. Although figured in a few recent popular shell books (Dance, 1974; Cernohorsky, 1978), it has been largely ignored in the scientific literature. This species is the sole survivor of a genus that was represented in the Tethys Sea during the Tertiary.

I noted in the 1977 issue of the *Kepple Bay Tidings*, a shell club newsletter, that specimens of this species had recently been taken at the Bellona Reefs in the Chesterfield Islands. During a recent collecting trip to New Caledonia, I acquired several preserved specimens and examined a few more preserved animals at the Australian Museum, Sydney. Although these specimens were poorly preserved, I was able to study the gross anatomy and to make a few histological preparations of this rare prosobranch. I have examined specimens from the major malacological collections, surveyed the literature and reviewed the fossil taxa of *Gourmya*. The results of this study establish *Gourmya* as a valid genus in the family Cerithiidae and define the geographic and ecological range of this relict species.

Abbreviations used in text:
AMNH – American Museum of Natural History
AMS – Australian Museum, Sydney
BM(NH) – British Museum (Natural History)
NMHNP – National Museum d'Histoire Naturelle, Paris
NMV – National Museum, Victoria
USNM – United States National Museum

Family *Cerithiidae* Fleming, 1828

Genus **Gourmya** Fischer

Gourmya "Bayle" (in MS), Fischer, 1884:680 (Type species, by original designation: *Cerithium gourmyi* Crosse, 1861). – Vignal, 1897:1-2. – Cossman, 1906:67-69. – Thiele, 1929:213. – Wenz, 1940:765, fig. 2215. – Nordsieck, 1968:69. – Cernohorsky, 1978:53.

Description – Stout, solid, turreted shell with moderately inflated whorls and large body whorl. Sculpture smooth to moderate with prominent thickened varix along edge of outer lip. Aperture large with deep anal canal and centrally located, tubular, straight siphonal canal. Base of outer lip extends over siphonal canal but is not attached to it. Radula typically cerithioid, taenioglossate (2+1+1+1+2). Pallial gonoducts open, males aphallic. Siphonal eyes present on inhalant siphon.

Remarks – Members of this genus first appeared in the Tethys Sea during the Eocene and

are found as fossils in the Paris Basin formation. The anatomy of the single, uncommon living species, *Gourmya gourmyi* (Crosse) unequivocally places it in the family Cerithiidae. *Gourmya* species are distinctive due to the unusual physiognomy of the shell aperture, anterior siphonal canal and outer lip; consequently, members of this genus are not easily confused with other cerithiid groups.

Fischer (1884) used the manuscripts of Bayle in proposing *Gourmya* (Cossmann, 1906:68) but Bayle should not be considered the author of the name, which is properly attributed to Fischer.

Nordsieck (1968:69) considered *Thericium* Monterosato, 1890, to be a subgenus of *Gourmya* and referred all Mediterranean species of *Cerithium* to *Gourmya*, but gave no reasons for this strange allocation. *Thericium* is normally regarded as a subgenus of *Cerithium* Bruguière, 1789, and members of the genera *Cerithium* and *Thericium* bear little or no resemblance to those of *Gourmya* in shell characters, certain anatomical features and ecology. I thus find Nordsieck's (1968) classification unacceptable.

Due to convergent shell characters, members of the genus *Terebralia* Swainson, 1840, family Potamididae Fleming, resemble *Gourmya*, and the living species, *Gourmya gourmyi*, was regarded by some earlier workers as a potamidid (see synonymy below).

Synonymy–

Cerithium gourmyi Crosse, 1861:171–173, pl. 6, figs. 1–2 (Holotype: NMHNP, not registered; Paratype: BM(NH) 1896.12.1.7; not registered; Type-locality: New Caledonia, here restricted to Nouméa).–Sowerby, 1866, pl. 290, fig. 325.–Vignal, 1897:1.–Cossmann, 1906:67.–Dance, 1974: 67.

Pyrazus Gourmyi Crosse. Sowerby, 1865; pl. 1, fig. 3.

Potamides (Terebralia) Gourmyi Crosse. Tryon, 1887:160, pl. 32, fig. 48.

Cerithium (–?) Gourmyi Crosse. Kobelt, 1888:6–8, pl. 1, figs. 4–5.

Cerithium (Gourmya) gourmyi Crosse. Cernohorsky, 1978: 53, pl. 14, fig. 1.

DESCRIPTION

Shell–(Fig. 1). Adult shell stocky, solid, turreted and comprising 19 moderately inflated whorls having apical angle of 40–45 degrees. Shell length ranges from 30–63 mm; shell width from 14–27 mm (see Table 1 for summary of shell measurements). Adult whorls slightly convex, sculptured with numerous fine spiral striae. Suture incised, distinct. Early whorls pink or white, usually eroded and with protoconch missing. Body whorl obese and with thick, smooth varix at edge of outer lip. Aperture circular-ovate, about one-third the length of the shell. Columella concave, smooth and lacking columellar callus. Anal canal (Fig. 1a) deeply incised, marked by strongly raised ridge extending well into shell aperture. Siphonal canal (Fig. 1d) straight, tubular, located at mid anterior of shell. Outer lip smooth, circular and begins at middle of body whorl. Base of outer lip extends, hook-like, over siphonal canal but is not fused to it (Figs. 1a, e, h). Periostracum yellow-tan, moderately thick and covering entire shell in fresh specimens. Shell color white, overlain with axial blotches of tan or brown. Intensity of color and pattern of blotches variable. Juvenile shells more typically cerithioid in shape. Anterior canal of juveniles less tubular than in adults and outer lip does not extend over siphonal canal. Operculum (Fig. 3g) ovoid, moderately thick, brown and paucispiral with nucleus near outer edge. Attached side with shiny attachment scar that is deeply impressed and marked with incised spirals and curves. Operculum fits snugly into aperture about one-third of the way back from outer lip.

Radula–(Fig. 2). Radular ribbon taenioglossate, long, about one-fourth the length of the shell and has 75 rows of teeth that show considerable wear at distal end. Rachidian tooth quadrate, about 0.12 mm long. Basal plate of rachidian has short rounded basolateral projection and longer basomedial projection. Central cusp of rachidian wide, spade-shaped, flanked on each side with two small pointed denticles. Top of rachidian has slight medial depression. Lateral tooth rhomboidal with flattened basal plate and slender basolateral extension. Cutting edge serrated with one sharp denticle, a long, wide triangular cusp and two to three small rounded denticles, respectively. Marginal teeth spatulate, curved at tips which are cusped on inner surface with a large pointed cusp at the tip and two smaller denticles on the inner side. In-

FIG. 1. *Shells of* Gourmya gourmyi, *showing apertural, dorsal, anterior and lateral views.* **a-d)** *Specimen from Brodie Cay, Marion Reef, 19°10'S, 152°17'E (AMS C108915; 44.4×20.6 mm);* **e-g)** *Specimen from Bampton Reef, Chesterfield Islands (AMNH 18002; 63×26.7 mm);* **h)** *Lectotype of* Cerithium gourmyi *Crosse, 1861 from New Caledonia (NMHNP, not registered; 42.3 mm long).*

TABLE 1. *Analysis of shell characters (measurements in mm).*

STATISTIC	No.	$\bar{x}$	Sd	Range
Shell length	19	44.3	8.72	30.4–63.3
Shell width	19	19.9	3.39	13.7–26.8
Len. aperture	19	14.8	3.23	10.7–24.1
Wid. aperture	19	9.7	2.37	5.9–16.6
No. whorls	19	8.5	1.15	6–11

No., number of snails; $\bar{x}$, mean; Sd, standard deviation.

ner marginals bear one cusp on outer side; outer marginals smooth.

Animal–(Fig. 3). The head-foot region of preserved snails is a pink-orange color. The broad head has relatively short cephalic tentacles, each of which bears a tiny black eye at its thickened base. The foot is large, broad, and has a deep propodial furrow that appears to be lined with numerous glandular cells that probably produce mucus. The mantle edge is lined with numerous wide and narrow papillae. The wider, longer papillae are separated from each other by three tiny narrow papillae (Fig. 3, *pp*). The exhalant siphon is marked by a deep fold and convex ridge on the external mantle surface (Fig. 3, *rex.*). The inhalant siphon is a long extension of the mantle edge and comprises several folds that form a deep latitudinal notch in the mantle (Fig. 3, *inho*). The undersurface of the inhalant siphon bears 6–7 thick, orange colored ocelli (Fig. 3, *inho*). Each ocellus is externally ovoid and has a small black circle in its center. Sections of the inhalant siphon show that the ocelli are indeed pit-shaped eyes. Each ocellus forms a deep invagination in the mantle and is surrounded by connective tissue within which may be seen neurites and a few small ganglia. A vertical section through an ocellus reveals a series of elongate epithelial cells with large nuclei at their proximal bases and capped at their distal ends with a cornea-like squamous epithelium. This bundle of elongate epithelial cells (Fig. 4, *ce*) is surrounded by tiny granules of black pigment (Fig. 4, *bp*). The entire structure probably functions as a lens. Light is concentrated in the rod-like epithelial cells and directed interiorly. Beneath the lens is a large spherical body of fine linearly arranged material (Fig. 4, *rd*) which may comprise many fine rods of retinal cells, but it appears acellular. At the base of the spherical body is a thin layer of large ovoid cells with dark

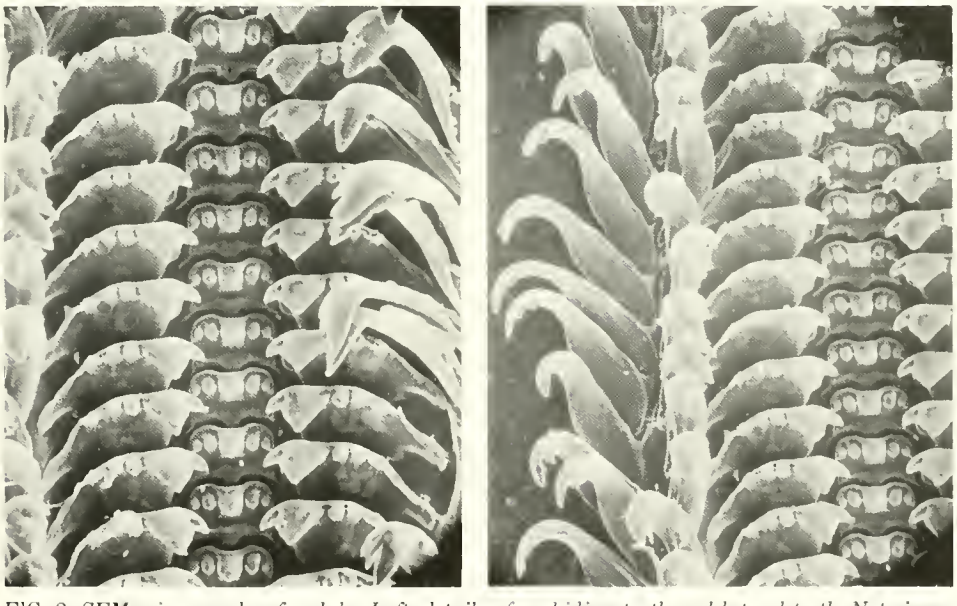


FIG. 2. *SEM micrographs of radula. Left: details of rachidian tooth and lateral teeth. Note inner marginal teeth at right, folded over laterals and showing the small cusp on outer lateral surface of tooth; Right: detail of half row of radular ribbon with marginal teeth folded back to show insertion on basal membrane. (Rachidian tooth 0.12 mm long).*

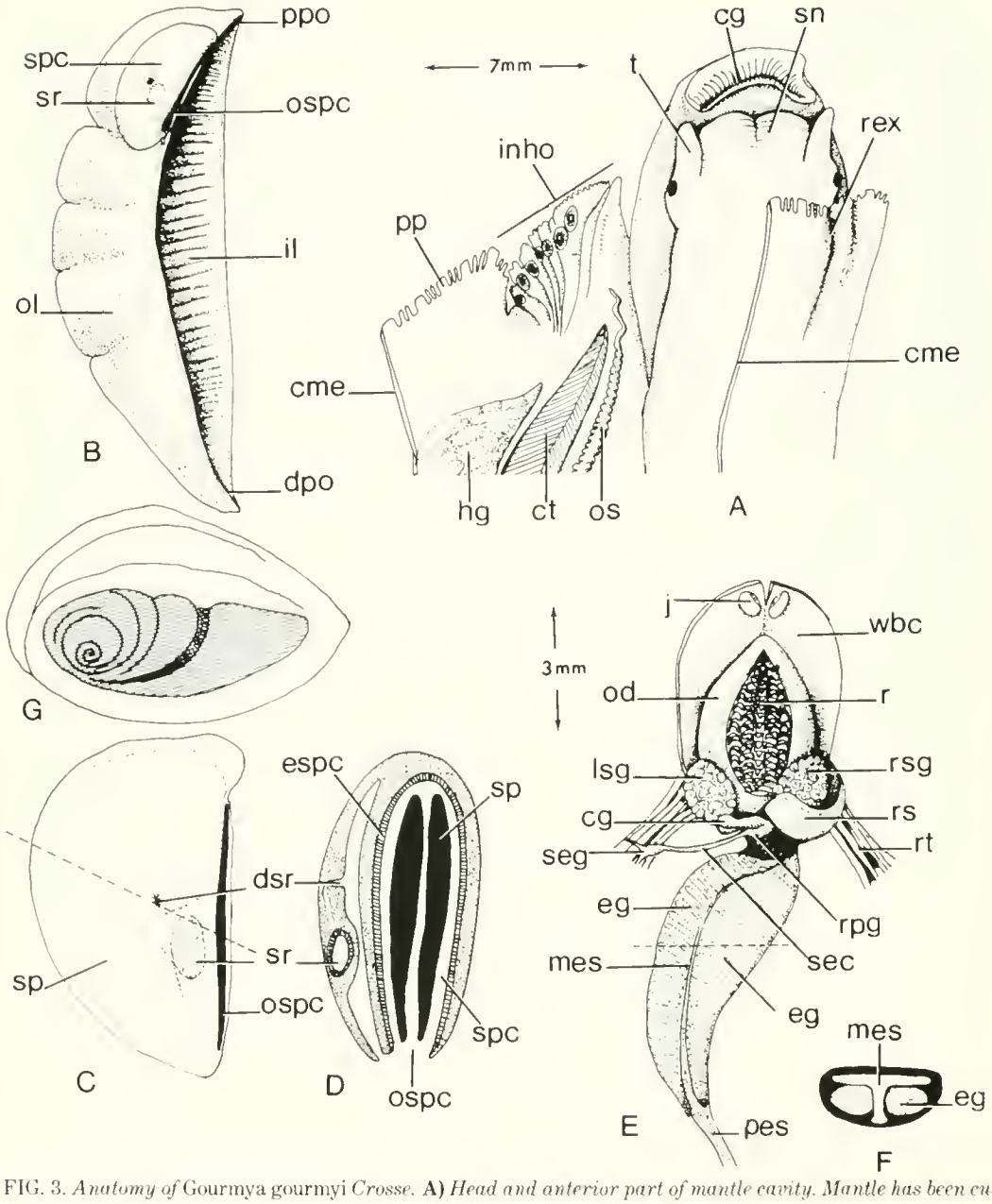


FIG. 3. *Anatomy of* Gourmya gourmyi *Crosse.* **A)** *Head and anterior part of mantle cavity. Mantle has been cut and folded to one side;* **B)** *Pallial oviduct removed from mantle cavity and oriented with distal portion at bottom; 15 mm length;* **C)** *Spermatophore chamber and seminal receptacle removed from pallial oviduct; 4 mm length;* **D)** *Cross-section of spermatophore receptacle and seminal receptacle made at dotted line in C;* **E)** *Anterior alimentary tract showing buccal mass, nerve ring and esophagus;* **F)** *Cross-section through mid-esophagus made at dotted line in E;* **G)** *Obverse of operculum showing attachment scar (shaded); 15 mm length;* **cg,** *ciliated groove;* **cme,** *cut mantle edge;* **ct,** *ctenidium;* **dpo,** *distal pallial oviduct,* **dsr,** *duct of seminal receptacle;* **cg,** *esophageal gland;* **espc,** *epithelial lining of spermatophore chamber;* **hg,** *hypobranchial gland;* **il,** *inner lamina;* **inho,** *inhalant siphon and ocelli;* **j,** *jaw;* **lsg,** *left salivary gland;* **mes,** *mid-esophagus;* **od,** *odontophore;* **ol,** *outer lamina;* **os,** *osphradium;* **ospc,** *opening to spermatophore chamber;* **pes,** *posterior esophagus;* **pp,** *pallial papillae;* **ppo,** *proximal pallial oviduct;* **r,** *radula;* **rex,** *ridge forming exhalant siphon;* **rpg,** *right pleural ganglion;* **rs,** *radula sac;* **rsg,** *right salivary gland;* **rt,** *radular tensor musele;* **sec,** *supraesophageal connective;* **seg,** *supraesophageal ganglion;* **sn,** *snout;* **sp,** *spermatophore;* **spc,** *spermatophore chamber;* **sr,** *seminal receptacle;* **t,** *tentacle;* **wbc,** *wall of buccal cavity.*

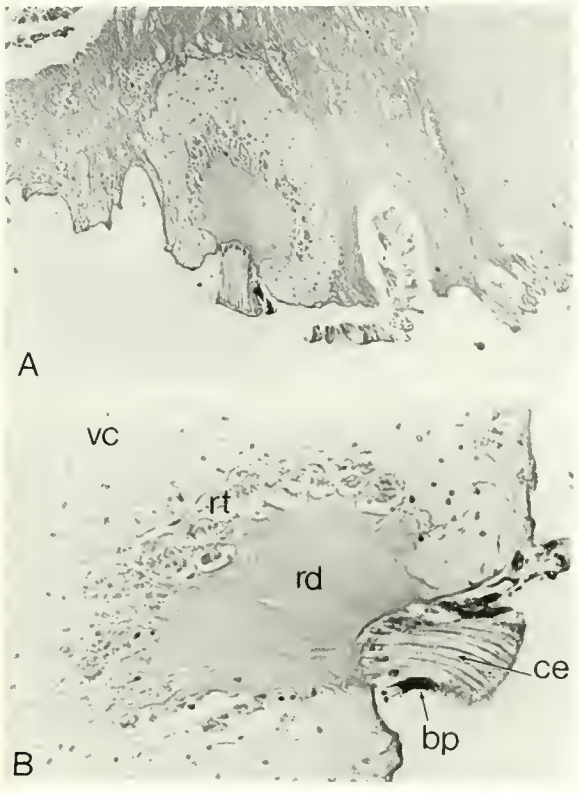


FIG. 4. *Longitudinal section through the inhalant siphon showing a pallial eye (Length of eye: 0.1 mm).* **A,** *Pallial eye in relation to mantle edge;* **B,** *Detail of pallial eye showing internal structure;* **bp,** *pigmented cells surrounding "cornea";* **ce,** *elongate epithelial cells comprising "cornea";* **rd,** *area interpreted as rods of retinal cells;* **rt,** *retinal cells;* **vc,** *vacuolated cells.*

staining cell walls and large nuclei filled with dark staining granules (Fig. 4, *rt*). These appear to be pigmented photoreceptor cells of the retina. A thick mass of large vacuolated cells with small nuclei and weakly defined cell boundaries surrounds the receptor cells. This last cell layer comprises most of the ocellus and is embedded in the muscular tissue of the mantle edge (Fig. 4, *vc*).

When the mantle cavity is opened by a dorsal longitudinal cut, the layout of the mantle organs is typically cerithioid.

The hypobranchial gland (Fig. 3A, *hg*) is a wide, thick structure extending back about one third the length of the mantle cavity. The rectum is a thick tube filled with several transverse layers of fine tubular fecal pellets that consist of fine carbonate sediment, green algal particles and detritus, and strands of filamentous green algae. It is detached from the mantle wall at its distal end where it becomes a free tube that opens about 3–4 mm behind the distal part of the pallial gonoduct. A deep fold in the mantle roof lies in apposition to the anus and corresponds to the exhalant siphonal ridge seen on the external mantle roof.

The osphradium (Fig. 3A, *os*) is tan, thin and bipectinate, lies close to the ctenidium, and extends most of the mantle cavity length. At its distal end it becomes a fine worm-like ridge which ends near the edge of the exhalant siphon. The ctenidium (Fig. 3A, *ct*) is monopectinate and comprised of numerous long triangular filaments.

The pallial gonoducts are open in both sexes and males are aphallic. This arrangement is typically cerithioid and may be compared with what has been described for other cerithids (Houbrick, 1971, 1976, 1978).

In females, the thick glandular pallial oviduct is basically a slit tube comprising outer and inner laminae (Fig. 3B, *ol, il*). There are no sperm collecting gutters or ducts in the wall of the outer lamina (Fig. 3B, *ol*) for most of its length, but the proximal end bears a large kidney-shaped spermatophore chamber (Fig. 3B, *spc*) in its wall. This lies close to the free edge of the outer lamina and appears as a large, light yellow structure with a finely wrinkled surface. When closely observed, the proximal part of the outer lamina is seen to be a complex structure that includes a seminal receptacle (Fig. 3B, C, D, *sr*) and internal duct as well as the spermatophore chamber (Fig. 3D, *spc*). The spermatophore chamber opens to the lumen of the pallial oviduct by a latitudinal slit on the free edge of the outer lamina (Fig. 3C, D, *ospc*) and may contain as many as two spermatophores. Spermatophores (Fig. 3D, *sp*) are pale yellow, tear shaped, and are roughly the size of the spermatophore chamber. They are placed with their rounded ends lodged in the proximal part of the chamber, and when present, cause the chamber to bulge. The interior of the spermatophore chamber is lined with columellar epithelial cells (Fig. 3D, *espc*). Another thin latitudinal slit lies

along the edge of the spermatophore chamber (Fig. 3D, *spc*) and within the free wall formed by this slit is found the seminal receptacle (Fig. 3C, D, *sr*).

The seminal receptacle appears to have a small duct (Fig. 3C, D, *dsr*) leading from it to the underside of the free wall. This opening is surrounded by fingerlike wrinkles and is easily seen. By means of this duct, sperm exit from the seminal receptacle into the slit and thence into the lumen of the pallial oviduct to fertilize ova as they move down the oviducal groove of the oviduct. There is no apparent connection between the spermatophore chamber and the seminal receptacle and its duct, but sperm are free to move from one slit to the other. The exact mechanism of sperm transfer is unknown. Tiny pink ova were seen in the oviducal groove and development is presumably indirect.

The alimentary system (Fig. 3E, F) of *Gourmya gourmyi* is that of a typical herbivorous cerithiid. The mouth lies at the top of a bilobed snout, recessed between the lobes. A pair of smooth ovate chitinous jaws (Fig. 3E, *j*) with smooth cutting edges, each about 1 mm long and 0.73 mm wide, lie at the anterior end of the buccal cavity. The buccal mass is large and the long radular ribbon (Fig. 3E, *r*) ends in a thickened radula sac that curls upwards (Fig. 3E, *rs*). Two thick radular tensor muscles (Fig. 3E, *rt*) extend from the walls of the head and insert laterally on the posterior buccal mass. The paired salivary glands are loose string-like lobes and lie dorsally on the dorsal buccal mass and anterior esophagus, in front of the nerve ring (Fig. 3E). A portion of the left salivary gland (Fig. 3E, *lsg*) passes through the nerve ring. No salivary ducts were found. Immediately behind the nerve ring the esophagus narrows and makes a sharp turn upwards, expanding slightly. The mid-esophagus (Fig. 3E, *mes*) has a deep ventral food groove and a broad, flat dorsal food channel (Fig. 3F). A large paired esophageal gland, (Fig. 3E, *eg*) comprising two longitudinal strips, lies along the mid-esophagus. (Fig. 3F). Sections of this gland show that it has many fine deep folds and diverticula which may be seen through its thin dorsal wall. The posterior esophagus (Fig. 3e, *pes*) has numerous longitudinal folds but is otherwise simple in structure. The stomach is basically the same as in other cerithiids. It is unusual in having a very large chitinous gastric shield with an extensive base and a main sorting area with numerous serially arranged leaflets.

The cerebral ganglia (Fig. 3E, *cg*) are about 2.1 mm long and are nearly fused, while the pleural ganglia lie below, close to the cerebrals. The supraesophageal connective (Fig. 3E, *sec*) is thick and the supraesophageal ganglion (Fig. 3E, *seg*) is moderately large. The RPG ratio (length of the pleuroesophageal connective divided by the sum of the length of the right pleural ganglion, the supraesophageal connective, and the supraesophageal ganglion) was 0.62, indicating a moderately concentrated nerve ring.

Records–LOYALTY ISLANDS: Maré Id (AMS C3714); NEW CALEDONIA: Nouméa (NMV); Bambui, Ile des Pins (AMNH 186748); 30 meters, reef near Dumbea, (USNM 795115); 29 meters, outer slope St. Vincent Reef, off Baie de Vincent (USNM 795116); CHESTERFIELD ISLANDS: 7 meters, NE end, Anchorage Id (AMS C. 86642); Bampton Reefs (AMS C 108914; C 108913); Seaward face of Ile Longue (USNM 795122); 9 meters Bellona Reef (Whitehead, 1977:3); AUSTRALIA: 5–25 meters top of coral bommies, Brodie Cay, Marion Reef, 19°10′S, 152°17′E (AMS C 108915).

DISCUSSION

Synonymic Remarks–Crosse (1861:173) named this species after Mr. Gourmy, from whose collection the first specimens were described. Several authors (Sowerby, 1865; Tryon, 1887) have mistakenly referred this species to the potamidid genera *Pyrazus* Montfort, 1810 and *Potamides* Brongniart, 1810, but the similarities in shell morphology are convergent. Members of the Potamididae are estuarine snails and differ considerably from marine cerithiids. Crosse (1861:173) compared *Gourmya gourmyi* with *Terebralia* species (potamidids) but noted that the latter were ecologically very different from the marine dwelling *Gourmya* species. He also compared *Gourmya* with *Cerithium adustum* Kiener, 1841. The latter species only resembles *Gourmya* superficially and never has the aper-

tural features that distinguish *Gourmya*. *Cerithium adustum* lacks the siphonal eyes, has a different radula and belong to the *Thericium* lineage. Kobelt (1888:8) was unsure of the proper allocation of *Gourmya gourmyi* and assigned it, with some doubt, near a group of species that he placed in the genus *Vertagus* Schumacher, 1817 (=*Rhinoclavis* Swainson, 1840) but which are now regarded as members of the genus *Pseudovertagus* Vignal, 1904 (Houbrick, 1978). He noted that the base of the outer lip of *Gourmya* was similar to that seen in *Pseudovergagus aluco* (Linnaeus, 1758). This similarity is superficial because the animals are quite different. Cossmann (1906) repeatedly spells *Gourmya* incorrectly as *Gourmyia*.

The pallial ocelli of *Gourmya* are unlike the well defined eyes found on its cephalic tentacles and on most mesogastropods. They appear to be more like the pit-shaped eyes of *Haliotis* as depicted by Welsch and Storch (1973:176–177) but differ from *Haliotis* by having a bundle of rod-shaped epithelial cells and a ring of dark pigment on the surface which I interpret as a lens. The ocelli somewhat resemble the eye of *Trichotropis* as shown by Fretter and Graham (1962:316). I have observed siphonal ocelli in one other cerithid, *Rhinoclavis (Proclava) kochii* (Philippi, 1848). *Rhinoclavis* species and some *Cerithium* species have large siphonal ganglia and elaborately pigmented inhalant siphons that seem to serve some sensory function. These have not been histologically investigated but probably bear some sensory structures. Johansson (1956) described a very similar eye in the potamidid *Tympanotonus*. Thus, the presence of siphonal ocelli in *Gourmya*, although unusual, is not unprecedented among the Cerithiinae.

The serially arranged leaflets in the sorting area of the stomach of *Gourmya* are similar to those I have seen in the stomach of *Campanile symbolicum* Iredale, 1917, family Campanilidae Douville, 1904 (Houbrick, 1980, in press). *Campanile* is another Tethyan relict and the last of a long lineage of a large family of Tertiary snails. This structure is not present in other anatomically known species of Cerithiidae and Potamidae.

Ecology–Gourmya gourmyi, although uncommon in museum collections, is probably not a rare gastropod in its restricted range and habitat. Cernohorsky (1978:53) stated that it lives in the intertidal zone but this is erroneous. All museum specimens have been collected at depths ranging from 5–30 meters and at an average depth of 17.5 meters on rocky substrata associated with coral reef slopes. According to Australian collectors, specimens are usually found on algal covered rocky surfaces on fore reef drop-offs. As divers using SCUBA investigate that zone in this part of the Pacific, more specimens will undoubtedly be found.

The most striking feature of the shell of this species is the unusual, centrally placed siphonal canal over which extends the base of the outer lip. These peculiarities of the aperture and siphon create a flattened circular apertural plane that allows the snail to withdraw its head and foot and clamp down on the hard substratum for protection. Communication with the external environment is maintained through the siphonal canal by means of the ocelli and sensory receptors on the siphonal mantle edge. Another deterrent to predation is the thickened varix on the edge of the outer lip. No observations have been made on living animals and their associations but most live-taken specimens have *Capulus danieli* (Crosse) attached near the shell apex. Stomach contents, fecal pellet analysis and the anatomy of the alimentary system indicate that *Gourmya* is a herbivorous grazer. The relatively long radular ribbon suggests a grazing habit on coarse surfaces.

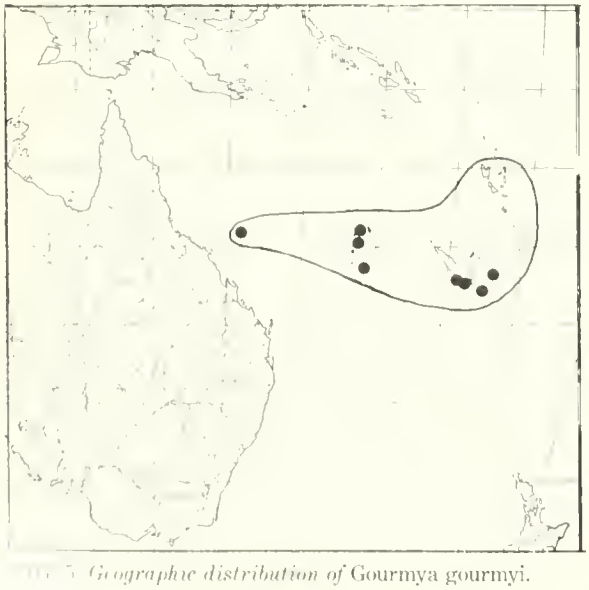
Fossil Record–Gourmya romeo (Bayan, 1870), a Tethyan Eocene species, is unequivocally a *Gourmya* species and is well illustrated by Bayan (1870: pl. 9, fig. 5) and Cossman (1906: pl. 1, figs. 8–9). Its shell shape is very close to the living species, *Gourmya gourmyi*. Cossmann (1906:68) stated that Bayle, whose manuscripts were used by Fischer (1884) in proposing *Gourmya*, designated *Cerithium romeo* Bayan as the "genoplesiotype" of *Gourmya*. Both Bayan (1870:37) and Cossmann (1906:68) noted its resemblance to the living species described by Crosse (1861:171–173) as *Cerithium gourmyi*, but it is unlikely that the two are conspecific.

An Oligocene species, *Cerithium ocirrohoe* Or-

bigny, 1850, has also been referred to *Gourmya* by Vignal (1897:69–70) and Cossmann (1906:69). I have not examined specimens of this species, but illustrations of it in the literature support its allocation to *Gourmya*. Cossmann (1906:69) further cited the Miocene species *Cerithium klipsteini* Michelotti, 1847 and *Cerithium geminatum* Grateloupe, 1832 (*non* Sowerby, 1816) as representatives of *Gourmya*. I have not seen these species and cannot comment on their allocation to the genus. I have examined the holotype of *Cerithium parungpontengense* K. Martin, 1899 (RMGM St 10391), a Pliocene species from Java, which, as K. Martin (1899:204) and Cossmann (1906:69) remarked, appears to be closely related to *Gourmya gourmyi*. I believe that this fossil is either the direct ancestor of *Gourmya gourmyi* or conspecific with it and am inclined to accept the latter opinion. Many other living cerithids have records extending back as far as the Miocene.

Geographic Range—(Fig. 5). The range of this species is restricted to the New Hebrides (Cernohorsky, 1978:53), New Caledonia, the Chesterfield Islands and Marion Reef, in the Coral Sea.

Conclusions—I regard *Gourmya* as a good genus because its lineage may clearly be traced in the fossil record to the Eocene. The living species' habitat in deeper waters of coral reefs suggests that members of this genus exploited an adaptive zone different from those of most other cerithiid groups. The peculiar features of the shell, such as the shape of the aperture, outer lip and siphonal canal, further set this group apart from other cerithiids. The presence of siphonal ocelli, a highly developed esophageal gland, large gastric shield and the arrangment of the spermatophore chamber and seminal receptacle at the proximal end in the outer lamina of the pallial oviduct are distinctive anatomical features that support the standing of *Gourmya* as a separate group. Open pallial gonoducts, aphallic males and the basic anatomy establish its inclusion in the Cerithiidae and suggest a close relationship with the genera *Cerithium* Bruguière, *Pseudovertagus* Vignal, and *Rhinoclavis* Swainson.



Geographic distribution of Gourmya gourmyi.

Members of the genus *Gourmya* were present in the Tethys Sea from the Eocene through the Miocene but became extinct after the Miocene and the closure of the Tethys. A fossil from Java confirms the presence of the genus in the Indo-Pacific during the Pliocene. The sole survivor of this lineage, *Gourmya gourmyi*, is today restricted to island groups in the Coral Sea around New Caledonia.

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CORBICULA FLUMINEA (BIVALVIA: SPHAERIACEA) IN BRITISH COLUMBIA[1]

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ABSTRACT

Corbicula fluminea (Müller) is reported from Vancouver Island, British Columbia. The specimens were located in the collection of the United States National Museum of Natural History and represent the first record of C. fluminea *in Canada and are the oldest documented specimens of the species in North America.*

Since the first report of *Corbicula fluminea* (Müller, 1774) in North America from specimens collected in 1938 in the Columbia River Basin of Oregon and Washington (Burch, 1944), these clams have spread across the United States and substantial populations now exist in 28 states (Sinclair and Isom, 1963; Fox, 1969, 1970; Clench, 1970, 1971; Eckbald, 1975; Crumb, 1977; Morris and Taylor, 1978; Britton and Morton, 1979; Mathiak, 1979). Clarke (1973), in an extensive review of the Mollusca of the Canadian Interior Basin, did not report *C. fluminea* from Canada and no other Canadian records for the species have appeared in the literature.

During a study of the zoogeography of bivalves in the genus *Corbicula* at the United States National Museum of Natural History, Washington, D.C., a lot of *Corbicula* (probably *C. fluminea*) collected in Canada was discovered (USNM 363020). The shells (3 specimens) were collected 24 February 1924 at Nanaimo, Vancouver Island, British Columbia by an unknown person and were sent to the United States National Museum by Mrs. Ida Oldroyd. The label accompanying the lot states "Dead on beach. Probably a Japanese import". No record of living *C. fluminea* at the collection site was found in the catalog.

Collections of freshwater mollusks by the Field Museum of Natural History (Chicago) at Nanaimo in 1953 did not reveal the presence of *Corbicula fluminea* (Haas, 1954). A review of distributional records for specimens in the genus *Corbicula* in the collections of the Museum of Natural Sciences, National Museums of Canada, Ottawa, the Nanaimo Mollusca collections of the Rev. G. W. Taylor at the Delaware Museum of Natural History and the collections of the Pacific Biological Station, Nanaimo, failed to reveal any additional records for *C. fluminea* in Canada (Muriel F. I. Smith, *pers. comm.*, 1979; R. Jensen, *pers. comm.*, 1980; D. Quayle, *pers. comm.*, 1980).

The introduction of *Corbicula fluminea* into North America is generally attributed to Chinese immigrants (Fox, 1969; Britton and Morton, 1979). There is, however, some debate as to when the introduction of this bivalve occurred. Fox (1969) postulated *C. fluminea* was introduced by immigrants from the Canton region who arrived in western North America during the late 1840's to work in the gold camps and mines and on the transcontinental railroad. Although there is an established tradition of eating *C. fluminea* among the Cantonese (who call it the Prosperity Clam) (Miller and McClure, 1931) it has not been established whether these clams could survive long periods in environments similar to those in ships of the period. Britton and Morton (1979) also attribute the importation of *C. fluminea* to the Chinese but place the introduction of the founding population sometime during the mid-1930's when many Chinese came to the United States and Canada to escape national and international conflicts in Asia. The present report places the arrival of *C.*

[1] University of Delaware College of Marine Studies Contribution No. 154

fluminea in North America during the early- to mid-1920's.

The absence of other Canadian records of *Corbicula fluminea* raises questions about its biology and distribution. Sport fishermen have used *C. fluminea* as a bait for many years (Fox, 1969; Britton and Morton, 1979) and the spread of this species in the United States has been attributed to these sportsmen who throw unused clams into streams (Britton and Morton, 1979). Abbott (1975) noted tropical fish hobbyists may similarly be responsible for the spread of these clams. Since *C. fluminea* is a consecutive protandrous hermaphrodite (Kraemer, 1978) very few clams are necessary to establish a population if environmental conditions are within acceptable limits for survival. It may be that USNM 363020 were discarded, either as bait or as the remains of a meal, into waters whose physicochemical characteristics were unsuitable. This speculation is not supported, however, by climatic, geologic and phytogeographic data for British Columbia (Clarke, 1973) which demonstrate that the environment of the southwestern portion of the province is like that of western Oregon and Washington and northern California where *C. fluminea* has thrived for over 30 years (Fox, 1969). The absence of *C. fluminea* in the Canadian Interior Basin (Clarke, 1973) and present-day British Columbia also supports the hypothesis recommended by Thompson and Sparks (1977) that *C. fluminea* is incapable of being carried to new localities in the gastrointestinal tract of migratory waterfowl.

The specimens in USNM 363020 are significant as they are the only record of *Corbicula fluminea* in Canada and also the earliest documented specimens of the species in North America.

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ANALYSIS OF SOME CHARACTERISTICS IN TWENTY FOUR POPULATIONS OF WESTERN U.S. PLEUROCERID SNAILS[1]

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ABSTRACT

Statistical analysis of the average obesity index and average apertural index in 24 populations of pleurocerid snails from the western United States indicates broad overlapping of those characteristics in Goniobasis plicifera *and* G. silicula *and a clustering of* G. orickensis, G. chacei, G. coquillensis, G. yreckaensis, G. hemphilli maupinensis, G. hemphilli dallesensis *and* G. plicifera bulimoides *distinct from the* G. plicifera-silicula *complex. This cluster of species and/or races needs to be re-elevated in order to determine interrelationships.*

INTRODUCTION

In its natural western U.S. range, the family Pleuroceridae was apparently rather widespread during Tertiary times (Henderson, 1935c), becoming progressively more segregated and depauperized in individual basins with the post-Pleistocene dessication of various drainages. At present, representatives of the family are distributed from British Columbia through western Washington and Oregon to northern California, but not extending south to San Francisco (Henderson, 1932). There are a few additional species in the western United States and Canada, such as the so-called *Goniobasis columbiensis* Whiteaves from the upper Columbia River in eastern British Columbia, a species which is probably conspecific with *G. livescens* (Menke) of the Niagara River and many Great Lakes tributaries (Goodrich, 1937). Furthermore, there are a few highly depauperized pleurocerids isolated in some Great Basin springs in Washoe County, Nevada, Lassen County, California, and some Columbia River tributaries. However, Goodrich (1935, 1944) judged these species to be more closely related to eastern U.S. species than to those of the Pacific slope.

It is the Pacific species which are very confusing. Henderson's (1935a, b) work on this group attempted to clarify some of the relationships, although additional confusion emerged; he did demonstrate the high degree of variability in the species and successfully delineated certain ranges. According to Goodrich (1935a), typical *G. silicula* (Gould, 1847) is confined to western Washington, although various authors have reported specimens under that name from Oregon and northern California. The race usually reported from northwestern Oregon is *G. silicula bairdiana* Lea, whereas *G. s. rudens* (Reeve) is the nominal race of the Olympic Peninsula. Another putative race in this species, *G. s. shastaensis* (Lea) was described from the Shasta and Scott rivers of California. *Goniobasis plicifera* (Gould) is distributed in northwestern Oregon and southwestern Washington (Henderson, 1935a) where it is supposedly not distinguishable from the nominal species *G. oregonensis* Tryon and *G. bulimoides* (Tryon) (Goodrich, 1942).

Other species described from the West Coast include *G. draytoni* Lea from Astoria, Oregon and Walla Walla, Washington, *G. acutifilosa* Stearns, *G. occata* (Hinds) from California (Henderson, 1935a) and *G. nigrina* (Lea) from headwater streams in Oregon and northern California (Goodrich, 1942). In addition, Henderson (1935a, b) described nine new species and subspecies: *G. hemphilli* from near Portland,

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Oregon, *G. hemphilli dallesensis*, the Dalles, Oregon, *G. hemphilli maupinensis*, Deschutes River, Oregon, *G. yrekaensis*, Shasta River, California and the Rogue River and creeks in adjacent Oregon, *G. yrekaensis obscura*, Wonder, Oregon, *G. orickensis*, Orick, California, *G. coquillensis*, Coquille River, Oregon, *G. chacei*, Smith River, Del Norte County, California, and *G. acutifilosa pittensis*, Fall River, California.

In reviewing the Pleuroceridae of the Pacific Coast, Goodrich (1942) separated all of the species into two main categories on the basis of sculpture and indicated that Henderson's (1935a, b) nine new forms were probably based upon trivial characteristics which were useful in distinguishing local races but not species and subspecies. Goodrich's (1942) categories included the *Goniobasis occata* group, with *G. occata* of the Sacramento and San Joaquin rivers in California and *G. acutifilosa* Stearns of Siskiyou and Shasta counties, California, and the *Goniobasis plicifera* (Lea) group, with *G. plicifera*, *G. silicula* and *G. nigrina* (Lea). Goodrich (1942) included *G. shastaensis* Lea, *G. rudens* Reeve, *G. rubiginosa* Lea and *G. bairdiana* Lea in the synonymy of *G. silicula*.

In addition, one of us (Branson, 1977) collected 55 specimens from the South Nemah River at Nemah, Washington, and 26 from Sutton Creek north of Florence, Oregon, which seemed intermediate in shell sculpturing and proportions between *G. plicifera* and *G. silicula*, stimulating the desire to conduct a more extensive comparison than possible at the time. Goodrich (1942) explained such observations by postulating that it might not be possible to make precise demarcations between some species, specifically *G. plicifera* and *G. silicula*.

Thus, the purpose of this paper is to present the results of a fairly extensive comparison of several of the western pleurocerid snails based upon two characteristics of the shell.

It has been known for a long time that the shell sculpturing in *G. silicula* is highly variable, tending to be well-developed in the main streams and nearly to completely absent in headwaters and springs (Goodrich, 1942). Such variation may result from differences in water chemistry, current, presence or absence of limestone, and climatic differences between headwaters and downstream sites (Bailey, Pearl and Windsor, 1932). There is also growth-related variation because of changes in relative proportions of height to width (Walker, 1900), a ratio that is also apparently influenced by exposure to wave action (Wiebe, 1926).

MATERIALS AND METHODS

Twenty four populations (see collecting data below) of pleurocerid snails from various West Coast localities were analyzed by straight forward analysis of variance and Student-Newman-Keuls *a posteriori* methods. Two characteristics were utilized, the "average obesity index", a feature which varies directly with average width and indirectly with average length (Wiebe, 1926) and the average apertural index, with similar relationships. Shell height was measured to the uppermost extent of the last suture to avoid bias caused by apex erosion, and the greatest girth was measured by means of dial calipers accurate to 0.01 mm.

COLLECTING DATA

In the following list, each station is assigned a number for ease of reference in the statistical tables and text. The names appearing in this list are those applied by the various authors of the forms indicated. The figures in parentheses are the sample sizes.

1. *Goniobasis plicifera bulimoides* (Tryon). Willamette River just above Eugene, Oregon (9).

2. *Goniobasis plicifera oregonensis* (Tryon). Small creek, 38 air miles north of Astoria, Oregon (7).

3. *Goniobasis circumlineata* Tryon. Geyser Creek, Sonoma County, California (2).

4. *Goniobasis hemphilli maupinensis* Henderson. Deschutes River at Maupin, Oregon (7).

5. *Goniobasis orickensis* Henderson. Redwood Creek at Orick, Humboldt County, California (15).

6. *Goniobasis yrekaensis obscura* Henderson.

Small creek, two miles south of Wonder, Josephine County, Oregon (16).

7. *Goniobasis draytoni* (Lea). Sonoma County, California (25).

8. *Goniobasis coquillensis* Henderson. Coquille, Oregon (3).

9. *Goniobasis chacei* Henderson. Bear Creek, Del Norte County, California (8).

10. *Goniobasis yrekaensis* Henderson. Shasta River, 3.4 km above mouth, Siskiyou County, California (19).

11. *Goniobasis hemphilli dallesensis* Henderson. Mill Creek, The Dalles, Oregon (17).

12. *Goniobasis silicula* (Gould). Black River, Washington State Route 12, Chehalis Indian Reservation (57).

13. *Goniobasis silicula*. Small spring, tributary to Black River, near Gray's Harbor, Washington (81).

14. *Goniobasis silicula*. East Fork of Satsop River, Schafer State Park, Washington (81).

15. *Goniobasis silicula*. Skokomish River, 0.5 km above mouth, Washington (24).

16. *Goniobasis silicula*. Cranberry Creek, near Ocosta, Washington (20).

17. *Goniobasis silicula*. Humptulips River, Humptulips Quadrangle, Washington (16).

18. *Goniobasis silicula*. Fairchild Creek, tributary to Humptulips River, Humptulips Quadrangle, Washington (29).

19. *Goniobasis silicula*. Caldwell Creek, Wynoochee Valley, Washington (17).

20. *Goniobasis silicula*. Scatter Creek, Tenino, Washington (7).

21. *Goniobasis silicula*. Small creek, 7 miles north of Vancouver, Washington (15).

22. *Goniobasis plicifera* (Lea). Small creek at Millersylvania State Park, Washington (22).

23. *Goniobasis plicifera*. South Nemah River, near coast, Washington (55).

24. *Goniobasis plicifera*. Sutton Creek, U.S. Highway 101, 6 miles north of Florence, Oregon (26).

DISCUSSION

As expected, the overall analysis of variance for the characteristics delineated above demonstrated very highly significant variance components ($P<0.001$). Because of this, a stepwise Newman-Keuls *a posteriori* test was calculated for both sets of characteristics (Tables 1, 2).

The first treatment (Table 1) divided the populations into two groups. Group A included the following populations: 1 (*G. plicifera bulimoides*), 4 (*G. hemphilli maupinensis*), 5 (*G. orickensis*), 6 (*G. yrekaensis*), 8 (*G. coquillensis*), 9 (*G. chacei*), 11 (*G. hemphilli dallesensis*) and 17 (*G. silicula*). Group B. included: 2 (*G. plicifera oregonensis*), 3 (*G. circumlineata*), 7 (*G. draytoni*), 12, 13, 14, 15, 16, 18, 19, 20, 21 (all *G. silicula*), 22, 23, 24 (all *G. plicifera*), and 10 (*G. yrekaensis*).

The second analysis divided the populations into three categories. Group A included: 2 (*G. plicifera oregonensis*), 10 (*G. yrekaensis*), 15, 16, 17, 19, 20 (all *G. silicula*), 22, 24 (*G. plicifera*); group B included: 1 (*G. plicifera bulimoides*), 3 (*G. circumlineata*), 4 (*G. hemphilli maupinensis*), 6 (*G. yrekaensis*), 7 (*G. draytoni*), 8 (*G. coquillensis*), 11 (*G. hemphilli*), 13, 14, 18, 21 (all *G. silicula*), and 23 (*G. plicifera*); and group C: 5 (*G. orickensis*), 9 (*G. chacei*), and 12 (*G. silicula*).

Excluding *G. circumlineata* and *G. draytoni*, the range of which is far outside that of the other forms (Sacramento River basin), these analyses make some important points. For one thing, they reaffirm Goodrich's (1942) observations that there is often broad overlap in the characteristics of *G. silicula* and *G. plicifera*, principally because of environmentally stimulated variability. It also appears that Goodrich (1942) was correct in assuming that *G. plicifera oregonensis* was merely a variant form of typical *G. plicifera*.

On the other hand, analysis of the average apertural index (Table 1) demonstrates a strong clustering of *G. orickensis, G. chacei, G. coquillensis, G. yreckaensis, G. hemphilli maupinensis, G. hemphilli dallesensis* and *G. plicifera bulimoides* as contrasted with the other forms. There is a modest bit of overlapping in the case of *G. yrekaensis* with population 10 in the *plicifera-silicula* complex. In the case of the second character (Table 2), the analysis shows three clusters with regard to Henderson's (1935a, b) species and races, one for population 10 (*G. yrekaensis* from the Shasta River), one for *G. hemphilli, G. hemphilli maupinensis, G.*

TABLE 1. *Average Apertural Index (width of aperture divided by length of aperture) for West Coast Populations of* Gonïobasis. * = *significance at P<0.05; ns = not significant.*

RANK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Y	.6005	.6056	.6120	.6248	.6296	.6314	.6315	.6484	.6513	.6595	.6694	.6755	.6766	.6801	.6814	.6869	.6900	.6944	.6950	.6959	.6990	.6999	.7020	.7107
N	15	8	3	16	7	17	8	10	21	14	54	19	7	28		19	2	21	23	65	3	7	12	55
1	----																							
	ns																							
2	.0051	----																						
	ns																							
3	.0115	.0064	----																					
	ns	ns																						
4	.0263	.0212	.0141	----																				
	ns	ns	ns																					
5	.0291	.0240	.0176	.0028	----																			
	ns	ns	ns	ns																				
6	.0309	.0258	.0194	.0046	.0018	----																		
	ns	ns	ns	ns	ns																			
7	.0310	.0259	.0195	.0047	.0019	.0001	----																	
	ns	ns	ns	ns	ns	ns																		
8	.0479	.0428	.0364	.0217	.0188	.0170	.0169	----																
	*	ns	ns	ns	ns	ns	ns																	
9	.0538	.0487	.0423	.0275	.0247	.0229	.0228	.0059	----															
	*	ns	ns	ns	ns	ns	ns	ns																
10	.0590	.0539	.0475	.0327	.0299	.0281	.0280	.0111	.0052	--														
	*	*	ns	*	ns	ns	ns	ns	ns															
11	.0689	.0638	.0574	.0426	.0398	.0380	.0379	.0210	.0151	.0099	----													
	*	*	ns	*	ns	ns	ns	ns	ns	ns	ns													
12	.0750	.0699	.0635	.0487	.0459	.0441	.0440	.0271	.0212	.0160	.0061	----												
	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns												
13	.0761	.0710	.0646	.0498	.0470	.0452	.0451	.0282	.0223	.0171	.0072	.0011	----											
	*	*	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns											
14	.0796	.0745	.0681	.0533	.0505	.0487	.0486	.0317	.0258	.0206	.0107	.0046	.0035	----										
	*	*	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns										
15	.0840	.0789	.0726	.0577	.0549	.0531	.0530	.0361	.0302	.0250	.0151	.0090	.0079	.0044	----									
	*	*	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns									
16	.0884	.0833	.0769	.0621	.0593	.0577	.0574	.0407	.0348	.0298	.0195	.0134	.0123	.0088	.0041	----								
	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns								
17	.0895	.0844	.0780	.0632	.0604	.0586	.0585	.0416	.0357	.0305	.0206	.0145	.0134	.0099	.0052	.0011	----							
	*	*	ns	*	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns							
18	.0939	.0888	.0824	.0676	.0648	.0630	.0629	.0460	.0401	.0349	.0250	.0189	.0178	.0143	.0099	.0054	.0044	----						
	*	*	ns	*	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns						
19	.0984	.0934	.0870	.0722	.0695	.0677	.0676	.0507	.0448	.0395	.0296	.0235	.0224	.0189	.0105	.0061	.0050	.0006	----					
	*	*	*	*	*	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns						
20	.0951	.0903	.0839	.0691	.0664	.0646	.0644	.0476	.0417	.0374	.0275	.0214	.0203	.0168	.0111	.0070	.0059	.0015	.0009	----				
	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns					
21	.0993	.0942	.0878	.0730	.0702	.0684	.0683	.0514	.0455	.0403	.0304	.0243	.0232	.0197	.0153	.0109	.0098	.0054	.0048	.0039	----			
	*	*	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns				
22	.0994	.0943	.0879	.0741	.0703	.0686	.0685	.0517	.0457	.0404	.0305	.0244	.0233	.0198	.0154	.0110	.0099	.0056	.0049	.0040	.0001	----		
	*	*	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns			
23	.1015	.0964	.0900	.0752	.0724	.0706	.0705	.0536	.0477	.0425	.0326	.0265	.0254	.0219	.0175	.0111	.0120	.0076	.0070	.0061	.0022	.0021	----	
	*	*	*	*	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	
24	.1102	.1051	.0987	.0839	.0811	.0791	.0792	.0623	.0564	.0512	.0413	.0352	.0341	.0306	.0262	.0211	.0207	.0163	.0157	.0118	.0109	.0108	.0087	----

TABLE 2. *Average Obesity Index of West Coast Populations of Goniobasis.* * = *significance at P 0.05; ns = not significant.*

ns=not significant.

RANK		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Y	.3867	.3907	.3968	.3989	.3989	.4003	.4097	.4222	.4273	.4275	.4329	.4376	.4450	.4456	.4503	.4452	.4610	.4623	.4683	.4692	.4865	.4919	.5012	.5014
	N	21	7	7	10	19	19	21	23	14	28	2	25	65	17	16	54	12	7	3	8	3	15	55	8
1		----																							
		ns																							
2		.0040	----																						
		ns	ns																						
3		.0101	.0061	----																					
		ns	ns	ns																					
4		.0122	.0082	.0021	----																				
		ns	ns	ns	ns																				
5		.0126	.0082	.0021	----	----																			
		ns	ns	ns	ns	ns																			
6		.0136	.0096	.0036	.0014	.0014	----																		
		ns	ns	ns	ns	ns	ns																		
7		.0230	.0190	.0129	.0108	.0108	.0094	----																	
		ns	ns	ns	ns	ns	ns	ns																	
8		.0355	.0315	.0254	.0233	.0233	.0219	.0125	----																
		ns	ns	ns	ns	ns	ns	ns	ns																
9		.0406	.0366	.0305	.0284	.0284	.0270	.0176	.0051	----															
		*	ns	ns	ns	ns	ns	ns	ns	ns															
10		.0408	.0368	.0307	.0286	.0286	.0272	.0178	.0053	.0002	----														
		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns														
11		.0462	.0422	.0361	.0340	.0340	.0326	.0232	.0107	.0056	.0054	----													
		*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns													
12		.0509	.0469	.0408	.0387	.0387	.0373	.0279	.0154	.0103	.0101	.0047	----												
		*	ns	ns	ns	*	*	ns	ns	ns	ns	ns	ns												
13		.0583	.0543	.0482	.0461	.0461	.0447	.0353	.0228	.0177	.0175	.0121	.0074	----											
		*	ns	ns	ns	*	*	ns	ns	ns	ns	ns	ns	ns											
14		.0589	.0549	.0488	.0467	.0467	.0453	.0359	.0234	.0183	.0181	.0127	.0080	.0006	----										
		*	ns	ns	ns	*	*	ns	ns	ns	ns	ns	ns	ns	ns										
15		.0636	.0596	.0535	.0514	.0514	.0500	.0406	.0281	.0230	.0228	.0174	.0127	.0053	.0047	----									
		*	*	*	ns	*	*	*	ns	ns	ns	ns	ns	ns	ns	ns									
16		.0685	.0645	.0584	.0563	.0563	.0549	.0455	.0330	.0279	.0277	.0223	.0176	.0102	.0096	.0049	----								
		*	ns	ns	ns	*	*	*	ns	ns	ns	ns	ns	ns	ns	ns	ns								
17		.0743	.0703	.0642	.0621	.0621	.0607	.0513	.0388	.0337	.0335	.0281	.0234	.0160	.0154	.0107	.0158	----							
		*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns							
18		.0756	.0716	.0655	.0634	.0634	.0620	.0526	.0401	.0350	.0348	.0294	.0247	.0173	.0167	.0120	.0171	.0013	----						
		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns						
19		.0816	.0776	.0715	.0694	.0694	.0680	.0586	.0461	.0410	.0408	.0354	.0307	.0233	.0227	.0180	.0231	.0073	.0060	----					
		*	ns	ns	ns	*	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns					
20		.0825	.0785	.0724	.0703	.0703	.0689	.0595	.0470	.0419	.0417	.0363	.0316	.0242	.0236	.0189	.0240	.0082	.0064	.0009	----				
		*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns				
21		.0999	.0958	.0897	.0876	.0876	.0862	.0768	.0643	.0592	.0590	.0536	.0489	.0415	.0409	.0362	.0413	.0255	.0242	.0182	.0173	----			
		*	*	*	*	*	*	*	*	*	*	ns	*	*	ns	ns	*	ns	ns	ns	ns	ns			
22		.1052	.1012	.0951	.0930	.0930	.0916	.0822	.0697	.0646	.0644	.0590	.0543	.0469	.0463	.0416	.0467	.0309	.0296	.0236	.0227	.0054	----		
		*	*	*	*	*	*	*	*	*	*	ns	*	*	*	*	*	ns	ns	ns	ns	ns	ns		
23		.1145	.1105	.1044	.1023	.1023	.1009	.0915	.0790	.0739	.0737	.0683	.0636	.0562	.0556	.0509	.0560	.0402	.0389	.0329	0,0320	.0147	.0093	----	
		*	*	*	*	*	*	*	*	*	*	ns	*	*	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	
24		.1147	.1107	.1046	.1025	.1025	.1011	.0917	.0792	.0741	.0739	.0685	.0638	.0564	.0558	.0511	.0562	.0404	.0391	.0331	.0322	.0149	.0095	.0002	----

plicifera bulimoides, G. coquillensis, and population 6 of *G. yrekaensis obscura,* and the third cluster for *G. orickensis, G. draytoni* and *G. chacei.*

Goodrich (1942) listed *G. plicifera bulimoides* as a synonym of *G. plicifera,* and all of Henderson's (1935a, b) other forms as species *incerta,* hinting that all of these were probably variants of either *G. plicifera* or *G. silicula,* or both. However, in view of the results reported here, this view does not appear acceptable. Goodrich (1942) himself stated that, "until a system of nomenclature shall have been devised that can deal with peculiarities of groups, clusters, or colonies, each by itself, it appears wisest to keep to the course followed in the treatment of the Pleuroceridae east of the Rocky Mountains." In the eastern United States, nearly every river system has its own peculiar pleurocerid fauna, even though some of the systems lie in close proximity to one another. If we follow Goodrich's (1942) logic, extrapolating the condition of eastern streams to the West, then it should follow that western drainages may also have experienced pleurocerid divergence so that differing drainages would possess differing species complexes of this complicated molluscan family. Hence, it is concluded that Henderson's (1935a, b) species, possibly including *G. plicifera bulimoides,* actually form a closely related complex of species and/or races as distinct from the *G. plicifera-G. silicula* complex. However, this complex needs to be re-evaluated as a group in order to determine interrelationships.

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A NEW RECORD OF *VALVATA SINCERA ONTARIENSIS* F. C. BAKER FROM MINNESOTA

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During the summer of 1970 a large series of mollusk and seed samples were obtained from the surface of sediments of lakes and ponds in northern Minnesota by Hilary Birks. One sample, from Little Spring Lake, Lake County, contained a specimen of the rare *Valvata sincera* forma *ontariensis* F. C. Baker.

Although the specimen is damagaed (part of the apex is missing, as is the terminal portion of the shell beneath the periostracum) it exhibits the loose coiling, round entire aperture, wide umbilicus, and the sharp, thin, lamellar ribs of the periostracum described by Baker (1931). The periostracal lamellae are fairly evenly spaced and most are directed posteriorly. With the periostracum removed, the shell would appear much like the form described by LaRoque (The Nautilis 46: p. 199) as *V. l. mccolli* from the late Wisconsin marl in Grey County, Ontario, Canada. I agree with Clarke (Malacologia 13: p. 225) that *mccolli* is a synonym of *ontariensis* but consider them to be forma, rather than true subspecies.

Little Spring Lake is located in a spruce forest in SW¼, sec. 29, T61N, R10W, about 20 miles southeast of Ely, Minnesota. The lake is small, being about 300 yards long and 150 yards wide. It is densely vegetated except for an open space in the east end, where the maximum depth attained is 11 feet. The specimen was collected about five yards offshore at the western end of the lake in about two feet of water. There the vegetation was dense (ca. 80 percent cover) and was dominated by *Nymphaea odorata, Nuphar variegatum, Potamogeton* (3 spp.), *Najas flexilis,* and *Megalodonta beckii.* Other mollusks taken from the bottom nearby include *Marstonia decepta, Valvata tricarinata, Gyraulus parvus, Valvata sincera, Sphaerium* sp., and *Pisidium* sp. The bottom sediments were fine-grained and muddy.

The only previously published records of *ontariensis* are from Ontario, Canada. The plate photographs were provided by Roger Woo. Hilary Birks (Cambridge University) provided the habitat data.

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FIG. 1. *Apical view of* Valvata sincera *forma* ontariensis, *Bell MNH No. P3578.* ×15.

FIG. 2. *Apertural view of the same specimen. The terminal portion of the last whorl is slightly distorted because the shell is missing beneath the periostracum.* ×15

THE FRESHWATER NAIADS OF ELK RIVER, WEST VIRGINIA WITH A COMPARISON OF EARLIER COLLECTIONS

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ABSTRACT

During the summers of 1978 and 1979 an extensive survey of the freshwater mussels of the Elk River was conducted. A total of eighteen species of unionacean clams, plus the exotic Asian clam, Corbicula fluminea, *were collected. A search of the collections of several museums produced evidence that earlier workers had, over the last one hundred years, taken a total of twenty-one species from the Elk River.* Lampsilis orbiculata, Dysnomia torulosa rangiana, Cyclonaias tuberculata *and* Lampsilis ovata, *which had been reported earlier, were not found and must be presumed no longer present in the Elk.* Corbicula fluminea *has spread throughout the Elk River.* Fusconaia m. maculata, Lampsilis radiata luteola, Elliptio dilatata, Ptychobranchus fasciolaris *and* Actinonaias ligamentina carinata *are presently the dominant species.*

Information on the freshwater naiads inhabiting the streams of West Virginia is all but non-existent. Until recently, the poor roads and rugged terrain of the region have made it rather difficult to reach most parts of the state. A few hardy individuals, most notably Dr. A. E. Ortmann, carried out limited expeditions into the state around the turn of the century. Other less well-known biologists have collected in West Virginia but none of their work was published, even though, fortunately, some of their material was deposited in museums around the country. Contemporary papers by Morris and Taylor (1979) and Taylor (1980) report mussel faunas of the Kanawha and Ohio Rivers, respectively. David Stansbery and Carol Stein (Ohio State University Museum of Zoology) have collected extensively throughout West Virginia in recent years but none of their work has as yet been published. We shall in this paper report material collected in the Elk River during the summers of 1978 and 1979, and in addition compare and contrast our findings with those of other investigators. We believe this to be the first extensive survey to have been carried out on the Elk.

THE ELK RIVER

The Elk River orginates in a sparsely populated mountainous area in Pocahontas County, W. Va., and flows approximately due west for 181 miles to its confluence with the Kanawha River at Charleston, W. Va. It traverses valleys with steep, high walls. Most of the basin is heavily forested and remains essentially untainted by man. The only pollutants present are those originating in a few local industries and a small amount of human sewage. The actual amount of raw sewage discharged into the stream is not known, but it probably has a significant effect on such water quality parameters as bacterial county, plant nutrients and turbidity (W. Va. Geological and Economic Survey, 1973). There are no major cities in the Elk River basin, and mining and timbering activity is limited, hence the Elk is a stream of fairly high quality. The bottom substrate consists primarily of cobble, silt and sand. The main stem of the Elk averages a fall of 168 feet per mile. The best collecting is in or near shoal areas. The river, throughout most of the collecting area, averaged 50 meters in width and less than two meters in depth.

METHODS

Shells were hand-picked from the shallows and river banks. Only live specimens, or those which obviously had been recently killed, were

collected. Specimens were returned to the laboratory where they were cleaned, positively identified and accessioned in to the Marshall University Malacological Collections. Voucher specimens have been placed with the Ohio State University Museum of Zoology. All scientific names used in this paper are those currently being used by Stansbery (1979). A total of 15 localities were designated as collecting sites and visited at irregular intervals during the two summers.

COLLECTING SITES

Site 1 60 yards down river from the base of Sutton Dam, near Sutton (Braxton County)

Site 2 along Rt. 16, 7.5 miles east of the Braxton/Clay County line (Braxton County)

Site 3 along Rt. 16, 3.2 miles west of the Braxton/Clay County line (Clay County)

Site 4 near a small roadside park on Rt. 16, 15.3 miles west of the Braxton/Clay County line (Clay County)

Site 5 along Rt. 16, 15.9 miles west of the Braxton/Clay County line (Clay County)

Site 6 Secondary Rd. 5, 4.3 miles west of intersection with Rt. 16 (Clay County)

Site 7 Secondary Rd. 5, 4.8 miles west of the intersection with Rt. 16 (Clay County)

Site 8 Secondary Rd. 5, 6.4 miles west of the intersection with Rt. 16 (Clay County)

Site 9 Secondary Rd. 5, near Camp Elk, 8.3 miles west of the intersection with Rt. 16 (Clay County)

Site 10 Secondary Rd. 5, downstream of Camp Elk, 8.7 miles west of the intersection with Rt. 16 (Clay County)

Site 11 Secondary Rd. 5, 3.0 miles east of the intersection with Rt. 4 (Clay County)

Site 12 Secondary Rd. 5, 2.4 miles east of the intersection with Rt. 4 (Clay County)

Site 13 small roadside park on Rt. 4 at the Clay/Kanawha County line

Site 14 below the bridge at Queen Shoals (Kanawha County)

Site 15 along U.S. 119 southeast of the Rt. 4–U.S. 119 intersection at Clendenin (Kanawha County)

RESULTS

A total of 18 species of unionacean clams, plus the exotic Asian clam *Corbicula leana*, were collected. These data are presented in Table 1. All collecting sites, with the execption of Site 1 (immediately below Sutton Dam), produced some usable material.

In order to get the most information available on previous collections made in the Elk River, the first author visited several museums (spring 1980) and searched the holdings for West Virginia material. The museums visited were as follows:

Field Museum of Natural History–Chicago
U.S.National Museum–Washington, D.C.
Carnegie Museum (Car. I.)–Pittsburgh
Ohio State University Museum of Zoology (OSU)–Columbus
Harvard University Museum of Comparative Zoology (MCZ)–Boston

The results of this search are presented in Table 2. Elk River specimens were found at the Ohio State University Museum, the Carnegie Institute Museum and the Harvard University Museum of Comparative Zoology.

In all, 21 species of unionids have been collected in the Elk River by earlier investigators. The vast majority of the museum material was collected 50 to 100 years ago, with most of the work having been done by Dr. A. E. Ortmann of the Carnegie Institute.

The only contempory report on the mussels of the Elk River was by Bates (1971). This paper was based on limited collecting (two localities–single collection at each) and listed only eight species. The species found by Bates were: *Elliptio dilatata, Fusconaia flava, Quadrula pustulosa, Actinonaias l. carinata, Lampsilis fasciola, Lampsilis ventricosa, Ligumia recta* and *Obovaria subrotunda*. With the exception of *Quadrula pustulosa* all species that Bates reported had been previously collected and were found in the museum collections.

In this paper we report *Lampsilis radiata luteola* (=*Lampsilis siliquoidea*) for the first time as appearing in the Elk River. This species, while never occurring in large numbers at any one site, nevertheless is quite widespread and was collected at 11 of the 15 designated sites.

Also reported for the first time in the Elk River is the exotic Asian import *Corbicula*

Table 1. Abundance and distribution of Elk River Mussels (R = Rare, M = Moderately Common, C = Very Common).

Species	Site No.														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Strophitus u. undulatus (R)											X		X		X
Lasmigona costata (M)		X				X	X		X			X	X		X
Quadrula p. pustulosa (R)		X					X	X	X	X					X
Amblema p. plicata (M)		X	X					X	X	X	X	X	X		X
Fusconaia m. maculata (C)		X					X	X	X	X	X	X			X
Fusconaia flava (R)					X										
Pleurobema clava (R)			X												
Pleurobema sintoxia (R)													X		
Elliptio crassidens (R)									X						
Elliptio dilatata (C)		X	X	X			X	X	X	X	X	X	X		X
Ptychobranchus fasciolaris (C)		X	X	X	X		X	X	X	X	X	X	X		
Actinonaias l. carinata (C)		X	X			X	X	X	X	X	X	X	X	X	X
Obovaria subrotunda (C)		X	X							X	X	X			X
Ligumia recta (C)		X	X	X	X		X	X	X	X	X	X			
Villosa iris (R)		X													
Lampsilis r. luteola (C)					X	X	X	X	X	X	X	X	X	X	X
Lampsilis ventricosa (C)		X	X		X		X	X	X	X	X	X			X
Lampsilis fasciola (R)		X						X	X						
Corbicula leana (C)		X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 2. Museum records from the Elk River (locality data are as they were recorded on original tags).

Species	Locality	Museum	Catalog No.
Strophitus u. undulatus	Gassaway	Car. I.	61.5397
	Shelton	Car. I.	61.5399
	Clay	Car. I.	61.5398
	Sutton	Car. I.	61.5395
Alasmidonta marginata	Gassaway	Car. I.	61.5382
	Shelton	Car. I.	61.5383
Lasmigona costata	Sutton	Car. I.	61.5366
	Shelton	Car. I.	61.5368
	Gassaway	Car. I.	61.5367
Amblema p. plicata	Mouth O'Brien Ck.	OSU	6514
	Below Sutton Dam	OSU	24702
	Mouth Twistabout Ck.	OSU	6420
	.2 mi. below Little Sandy Ck.	OSU	23112
	Sutton	Car. I.	61.5262
	Gassaway	Car. I.	61.5265
	Shelton	Car. I.	61.5266
Fusconaia m. maculata	Below Queen Shoals Bridge	OSU	23227
	Mouth of Laurel Ck.	OSU	6411
	Below Sutton Dam	OSU	24703
	Below King Shoals Run	OSU	44379
	Gassaway	OSU	45026
	Mouth O'Brien Ck.	OSU	45013

Fusconaia flava	Below mouth Little Sandy Ck.	OSU	23113
	Below Blue Ck. bridge	OSU	23034
	Mouth Twistabout Ck.	OSU	7901
	Mouth Twistabout Ck.	OSU	6418
	Mouth O'Brien Ck.	OSU	6513
	Rt. 11 bridge N.E. of Clay	OSU	44650
	Frametown	OSU	44998
	Glendon	OSU	44976
	Elkhurst	OSU	44931
Cyclonaias tuberculata	Rt. 64 bridge 2 mi. N.W. of Kelso	OSU	24996
	Mouth Twistabout Ck.	OSU	7905
	5.8 mi. W. of Fayetteville	Car. I.	61.5301
Pleurobema clava	Mouth O'Brien Ck.	OSU	6516
	Below Sutton Dam	OSU	24704
	Mouth Buffalo Ck.	OSU	44651
	1 mi. N.E. of Clay	OSU	44551
	Frametown	OSU	44999
	Gassaway	OSU	45027
	Above Twistabout Ck.	OSU	43882
	Glendon	OSU	44977
	Shelton	Car. I.	61.5325
	Gassaway	Car. I.	61.5324
	Sutton	Car. I.	61.5323
Pleurobema sintoxia	At Twistabout Ck.	OSU	43883
Elliptio crassidens	.2 mi. below Queen Shoals	OSU	23228
	Frametown	OSU	45000
	Glendon	OSU	44978
	Gassaway	Car. I.	61.5327
	Gassaway	Car. I.	61.5339
	Shelton	Car. I.	61.5328
	Sutton	Car. I.	61.5335
	Clay	Car. I.	61.5340
Ptychobranchus fasciolaris	1 mi. N. of Clay	MCZ	185594
	Above Twistabout Ck.	OSU	6424
	Above Twistabout Ck.	OSU	7910
	Shelton	Car. I.	61.5410
	Shelton	Car. I.	61.5411
	Sutton	Car. I.	61.5406
Actinonaias l. carinata	Gassaway	MCZ	262800
	1 mi. N. of Clay	MCZ	185596
	Shelton	Car. I.	61.5451
	Gassaway	Car. I.	61.5449
Obovaria subrotunda	Below Sutton Dam	OSU	24706
	Rt. 64 bridge 4 mi. E. Fayetteville	OSU	16182
Truncilla truncata	Mouth O'Brien Ck.	OSU	6527
	U.S. Rt. 64 bridge E. of Fayetteville	OSU	19062
Ligumia recta	Mouth O'Brien Ck.	OSU	6521
	Mouth Twistabout Ck.	OSU	7913
	Shelton	Car. I.	61.5504
	Clay	Car. I.	61.5503
	Gassaway	Car. I.	61.5502
Villosa i. iris	Above Twistabout Ck.	OSU	43890
	Elkhurst	OSU	44938
	1 mi. N.E. of Clay	OSU	44558
	Mouth Buffalo Ck.	OSU	44658
	5 mi. E. of Fayetteville	OSU	19066
	Shelton	Car. I.	61.5493
	Sutton	Car. I.	61.5492

Species	Locality	Museum	Catalog No.
Lampsilis ventricosa	1 mi. N. of Clay	MCZ	185597
	Gassaway	MCZ	262794
	Shelton	Car. I.	61.5538
	Gassaway	Car. I.	61.5536
	Sutton	Car. I.	61.5535
	Clay City	Car. I.	61.5537
Lampsilis orbiculata	.5 mi. below mouth of King Shoals	OSU	44386
Lampsilis ovata	Shelton	Car. I.	61.5527
	Clay	Car. I.	61.5526
Lampsilis fasciola	Gassaway	MCZ	262795
	Mouth O'Brien Ck.	OSU	45024
Epioblasma torulosa rangiana	Elkhurst	OSU	44962
	Mouth O'Brien Ck.	OSU	6526
	Mouth O'Brien Ck.	OSU	45025

fluminea (also referred to as *manilensis* Philippi and *leana* Prime). Thomas and Mackenthun (1964) were the first to recognize *Corbicula* in the Kanawha River at Charleston, W. Va. near the mouth of the Elk River. It has since spread into the Elk and is presently distributed throughout our study area as far upstream as Sutton Dam.

Of the 21 species reported by earlier investigators, we did not find the following six: *Alasmidonta marginata, Cyclonaias tuberculata, Epioblasma torulosa rangiana, Lampsilis orbiculata, Lampsilis ovata* and *Truncilla truncata.*

The Elk River is a stream of fairly good quality and is at the present time supporting a good population composed of a relatively large number of kinds of unionid mussels. *Fusconaia m. maculata, Lampsilis r. luteola, Elliptio dilatata, Ptychobranchus fasciolaris* and *Actinonaias l. carinata* are the dominant species in the Elk River. Only two specimens of *Pleurobema clava* were found in the entire study. This species is very nearly extinct in this river at this time, while fairly large collections of it were made 50 years ago. A single fresh specimen of *Elliptio crassidens* was found. It is our belief that this species is also in danger of extinction in the Elk River in the very near future.

ACKNOWLEDGMENTS

Special thanks to the museum curators who so graciously opened the collections to me. To the many others associated with the museums, I extend my heartfelt appreciation (R. W. Taylor).

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NEW RECORDS OF *ALLOPOSUS MOLLIS* VERRILL (CEPHALOPODA, OCTOPODA) FROM THE PACIFIC OCEAN

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ABSTRACT

Two specimens of Alloposus mollis *(Alloposidae) captured off southern California are described and illustrated. The anatomical characteristics of the species are discussed, and its distribution is reviewed.*

Alloposus mollis is a relative rarely captured mesopelagic cephalopod. Records of this species are few and locations scattered. The published illustrations and descriptions are rather incomplete and diagrammatic because of the lack of specimens in good condition of preservation.

Verrill (1880) originally described the species from specimens collected off New England in the North Atlantic. Additional specimens were reported by Verrill (1881) and Hoyle (1886) from off Newport, Rhode Island, the mouth of the Chesapeake Bay, and in other parts of the Atlantic (Joubin, 1895, 1900; Robson, 1930 for his *A. hardyi*; Thore, 1949; Adam, 1960). Ijima and Ikeda (1902) described an allied species, *A. pacificus*, from the Sagami Sea, Japan, and this species was recorded also for Sagami Bay, Japan, by Sasaki (1929). Berry (1914) suggested that the evidence was not sufficient to warrant two different species. Similarly, *A. hardyi* is believed to be synonymous with *A. mollis* (Thore, 1949). Specimens belonging to the family Alloposidae obtained at Pailolo Channel, Hawaii and other ALBATROSS stations in the Pacific (Hoyle, 1904; Berry, 1914) were considered to belong to *A. mollis*. Alloposidae material from the DANA collections, including specimens from the Atlantic, Indo-Pacific (05°52′N, 131°14′E) and the Indian Ocean (04°52′N, 77°08′E), were placed by Thore (1949) under *A. mollis*. Young (1972) obtained one specimen from Santa Catalina Basin, California (33°23′N, 118°49′W). This specimen, judging from the illustrations, was not complete and in bad condition of preservation, facts also explained by Young (1972) when he comments ". . . very large, but rather poorly preserved specimen".

Two specimens of *A. mollis* in excellent condition were taken off the southern California coast during survey cruises conducted by the National Marine Fisheries Service's R/V DAVID STARR JORDAN. These records together with the one by Young (1972) are the first reported specimens obtained from the North American Pacific. This report documents these records, provides a description and illustration of the specimens and review, the distribution and external morphology of the species.

Alloposus mollis Verrill, 1880

Material examined—The specimens collected were: Specimen A (200 mm total length, head and mantle) captured July 18, 1976 (2349 hours PST) at 33°23′N, 117°43′W in a six feet Isaacs-Kidd midwater trawl towed to a maximum depth of 70 m; and Specimen B (67 mm total length, head and mantle to base of arms) collected March 24, 1977 (0410 hours PST) at 33°31.8′N, 117°58′W, in a midwater trawl towed at a maximum depth of 7 m. Both specimens were females.

Description—These animals are ovoid in shape, widest at the head region. They are soft and of smooth gelatinous consistency, translucent, and covered with small red spots, giving the whole animal a brick-purple color. The head is large, short and slightly broader than the body. The mantle opening is wide and full, and in two broad pouches, extending dorsally from

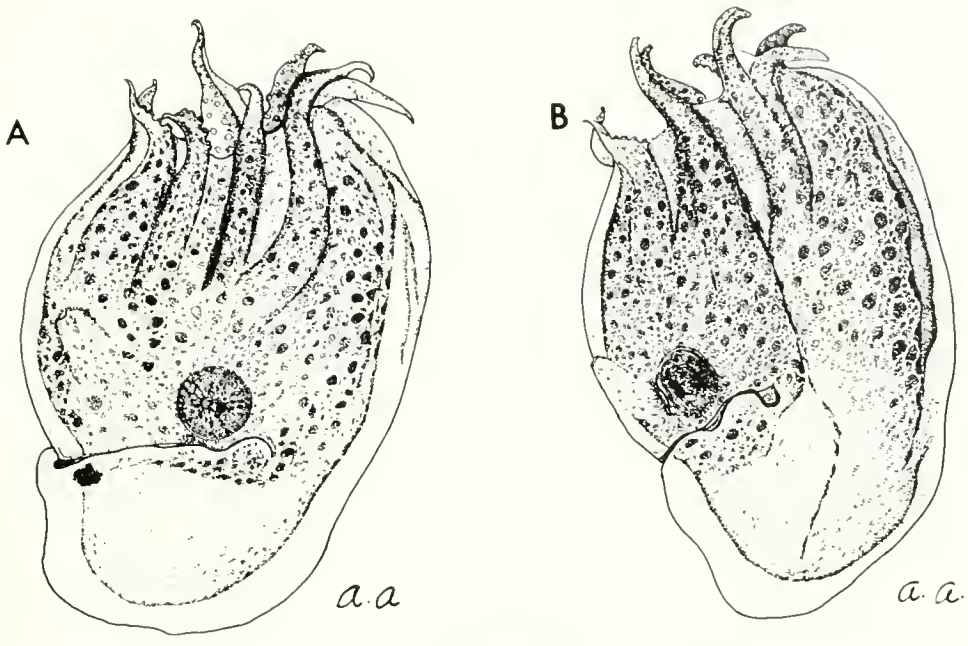

FIG. 1. **A**–*Lateral left view of* Alloposus mollis *(Specimen B);* **B**–*Dorso lateral left view of* Alloposus mollis *(Specimen B).*

the ventral point of the commissure towards the level of the eyes (Fig. 1). The eyes are large and prominent, covered by the eye lid. The lid has a small central opening which can be expanded to expose the entire eye (Figs. 2A and 2B). The funnel is large and is embedded with the gelatinous tissue of the head, except for the top which is free, reaching to a level higher than the upper edge of the eyes. The olfactory organ, a flat round lump, is located posteriorly to the eyes.

The arms are stout and short, relative to the body length (head and mantle), and they decrease in length from the dorsal to the ventral side. They are connected at the base by a broad membrane, web or umbrella, which attains the greatest extension between the dorsal pair of arms. The suckers are arranged in a straight row of 3 to 4 (ventral arms) or 4 to 6 (dorsal arms), from the mouth to the point on the arm where the web starts. At this point the suckers begin to deviate from a straight course to an incipient zig zag arrangement, which becomes more evident along the webbed and the free part of the arms (Fig. 2C). This pattern occurs in both specimens we collected, in Verrill's syntype, and in all other specimens we received from the Division of Mollusks at the Smithsonian Institution, which included the material examined by Berry (1914). Measurements from our specimens are given in Table 1.

Discussion–The arrangement of the suckers on the arms is an important character and subject to some disagreement and confusion in the literature. Ijima and Ikeda (1902) described an allied species, *A. pacificus*, from the Sagami Sea, subsequently reported by Sasaki (1929) from the same body of water in the Sagami Bay, Japan. Berry (1914) stated that the anatomical differences between *A. pacificus* and *A. mollis* were insufficient to establish a new species. According to Ijima and Ikeda (1902) the suckers of *A. pacificus* were arranged in a single row for most of the length of the arm, and were biserially arranged only on the free part of the arm, that is, from the edge of the web to the outer tip of the arm. This same characteristic was mentioned by Robson (1930) for *A. hardyi.* Verrill (1880) specifies that the suckers are "large, single, in two alternating rows," and Verrill

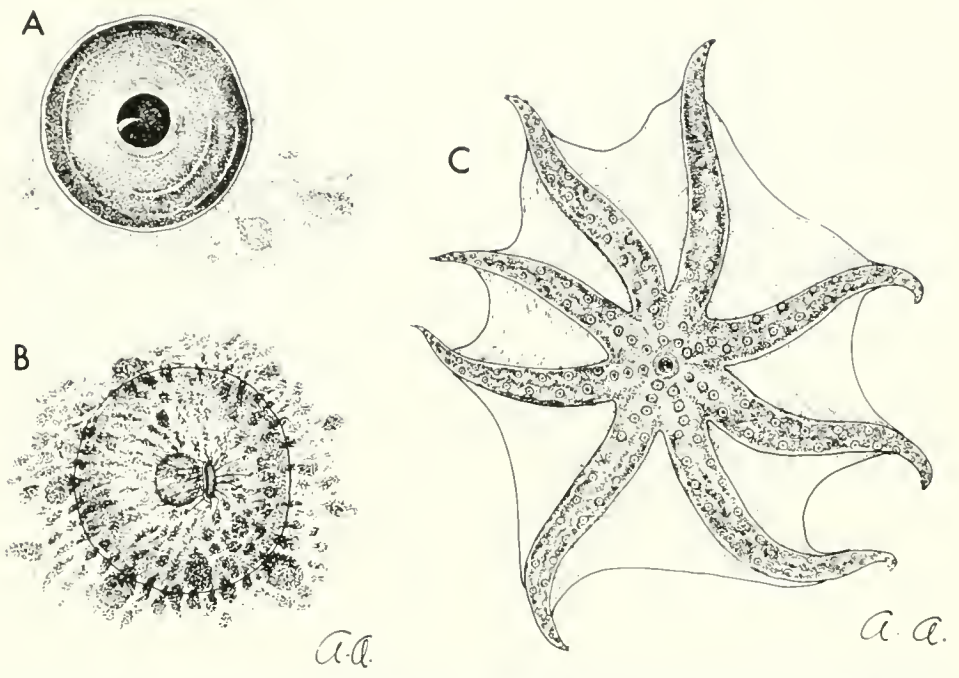

FIG. 2. **A**–*Eye with the eyelid expanded, exposing the eye (Specimen A);* **B**–*Right eye with sphincter of eyelid contracted; the diameter of the opening corresponds to that of the pupil of the eye (Specimen B);* **C**–*Detail of the crown of arms and interarms web, and the disposition of the suckers of female* Alloposus mollis *(from both Specimen A and Specimen B).*

(1881) states that the suckers "are in two rows or rather in a single more or less zig zag row which most conspicuously approached the two rowed condition after reaching the margin of the umbrella (at about the 13th sucker on the dorsal arms)." Robson (1930) explained for *A. hardyi* that "suckers tend to be uniserial or very widely alternating except about or just beyond the margin of the web, where they are more or less biserial." The suckers in our specimens are arranged, as explained above, in a straight row from the mouth to the point where the web starts, and at this point the suckers initiate an incipient zig zag arrangement, which becomes clearly evident along the webbed and free part of the arms (Fig. 2C). The suckers are 1 to 12 mm in diameter and their number varies from 12 (Thore, 1949) to 155 per arm (Joubin, 1900).

The proportions of the body in *A. mollis* change slightly with age; older specimens have relatively shorter bodies and longer arms than young individuals.

The only sexual dimorphism in Alloposidae is the third right arm, hectotylus of males. The males have 7 normal arms and the hectotylized arm. Verrill (1881) reported a hectotylus reaching 200 mm in length and 20 mm in width, with two rows of large 4-mm diameter, 6 or 7 lobed suckers, with a terminal process 30 mm long and 7 mm diameter.

Most of the specimens of *A. mollis* obtained by other authors were partially destroyed, injured during trawling, or only fragments of large individuals. Our specimens were alive and in excellent condition when brought on deck, and the morphological structures were accurately maintained (Fig. 3). No dissections were made to examine the internal atatomy or stomach content, because we felt it was important to keep the specimens in good conditon.

TABLE 1. *Meristic data on the specimens of* Alloposus mollis *collected off California.*

	Total length mm	Width mm	Head width mm	Length funnel mm	Eye diameter mm	Diameter open. eye lid mm	Width mantle mm	No. suckers mm	Size suckers mm
Specimen A	200	65	76	36	26	3	80	>80	3 to 1

Total length of arms from ventral to dorsal

	right	left
I	82	76
II	88	82
III	92	85
IV	120	117

Length of free part of the arms

	right	left
I	43	40
II	40	37
III	52	50
IV	85	82

Specimen B	67	38	40	16	8	1	42	20-30	1.5 to <1

Total length of arms from ventral to dorsal

	right	left
I	24	20
II	35	32
III	36	34
IV	40	40

Length of free part of the arms

	right	left
I	12	10
II	15	15
III	18	17
IV	22	22

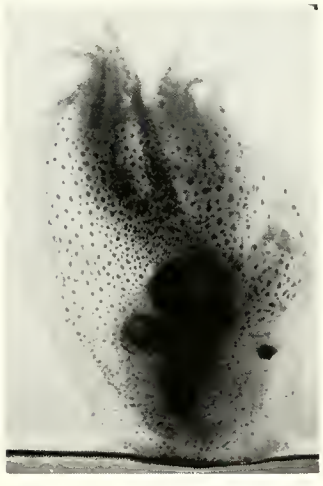

FIG. 3. Alloposus mollis *(Specimen B), length 67 mm.*

Distribution—*Alloposus mollis* is a cosmopolitan species, usually found near tropical and subtropical oceanic regions (Tables 2 and 3; Fig. 4). The majority of the deep-sea cephalopods were collected in trawls and probably are adept at avoiding nets of all types. The capture of our specimen B (Fig. 3) was observed by biologists on deck of vessel, and it was efficiently avoiding capture, when net was directly towed in pursuit of the specimen. Similarly, Thore (1949) suggested that *A. mollis* may only appear to be rare because of their ability to avoid capture. *A. mollis* may inhabit the open sea during certain phases of its life cycle, and remain in deep and bottom layers of the continental slope during other (Thore; 1949).

Our specimens were both juvenile females

TABLE 1. Comparison of world data on *Architeuthis mollis* Verrill.

Location	Size	Length of body to base of arms	Mantle	Width of body	Head width	Length arms	Tent. arms	Number of suckers on arm I	arm II	Diam. suckers	Description of suckers on arms	Size of ages	Sex	Depth	Temp. °C	Author
39°48' N, 70°50' W 39°46' N, 71°05' W 39°52' N, 70°52' W 39°56' N, 70°55' W 37°24' N, 74°17' W 38°27' N, 73°32' W		90 mm		70 mm		Dorsal 60 mm longer than ventral					Arranged in one or two rows	Large				Verrill, 1880
100–150 miles south of Newport, Rhode Island	160 mm	90 mm	50 mm	70 mm		70				7 mm	In one or two rows					Verrill, 1881
38°52' N, 38°33' W – 59°34' N, 64°23' W																Verrill, 1884
North Atlantic																Hoyle, 1886
42°45' N, 22°15' W to 47°32' N, 43°25' W							70	60	130	70 mm						Joubin, 1895
27°55' N, 27°44' W and 38°24' N, 25°22' W						650 to 1610 mm		100	155							Joubin, 1900
Sagami Sea, Japan											Multiple row on most part of arm and biserially arranged only on three top					Ijima and Ikeda, 1902
30°09' N, 30°34' W																Hoyle, 1904
Pandora Channel, Hawaii	47+	65 mm		46–5		570–32				4 mm	In 2 rows or reticulate a single irregular pattern after reaching length umbrella					Berry, 1914
30°56' N, 147°30' W			40 mm	25	36	50–1 E					Tend to uniserial or alternating, except beyond mantle of web, when adopt biserial pattern		w	Dw		Robson, 1930
16°06' N, 76°02' W	13		5		6 5	6 5		15	1					33	13°50	
25°–25°9 and 74°–45°W																
19°37' N, 18°05' W	29		11 3		30	15		17	4	2		10 3	w	33	"	
38°25' N, 15°11' W	44		13 3		41 3	22.8		1	12	2 3		14	w	33	"	
36°37' N, 18°06' W	52		25 3		49 4	31 2		25	17	2 5		17 1	w	33	"	
19°37' N, 18°03' W	60, 70		22 8, 26 2		60, 1	33, 43 1		26, 25	25	2 6, 4 5		27, 28 9	F	33	"	
37°23' N, 26°09' W – 37°45' N, 25°50' W	91		34 5		3	59 1		30	25	3 4		36 4	w	333	9°18–11°39C	
25°52' S, 130°14' E 34°32' N, 177°38' E	450		100		447	343				5		152	F	333	"	
27°10' N, 28°59' E													2 sps 1 ♀			Thore, 1949
east of Cape Town, South Africa			30–60					260+	220	5		35	w	300–550		Adam, 1960
Santa Catalina Basin (33°23' N, 119°45' W)			115	105	120	360–200						55	F			Young, 1972

TABLE 3. *Data on specimens from the Smithsonian Institution.*

Number of specimens	Total length mm	Position	Depth m	Date
1 male	120	39°52'N-70°58'W (off Rhode Island)	680	1880
1 *	60	Hawaiian Islands (Pailolo Channel)	530.4	22 July,1902
4 males	variable	21°06'N-156°13'W (Hawaiian Islands)	686	5 April,1968
1 *	120	21°01'N-156°43'W (Hawaiian Islands)	548.7	17 Nov., 1968
1 *	55	12°24'N-82°24'W (Caribbean Sea)	612.7	22 Nov., 1968
Several *	medium	28°17'N-86°21'W (Gulf of Mexico)	671	20 June, 1969
2 *	55	18°52'N-94°50'W (Gulf of Mexico)	612.7	5 June, 1970
1 *	large	24°24'N-87°49'W (Gulf of Mexico)	567	14 Aug., 1970
1 *	45	28°00'N-85°20'W (Gulf of Mexico)	521	27 Aug., 1970
1 *	88	29°46'N-88°25'W (Gulf of Mexico)	36.5	14 April,1972

* Due to bad condition of preservation of specimens, sex could not be determined.

Total length includes head and mantle.

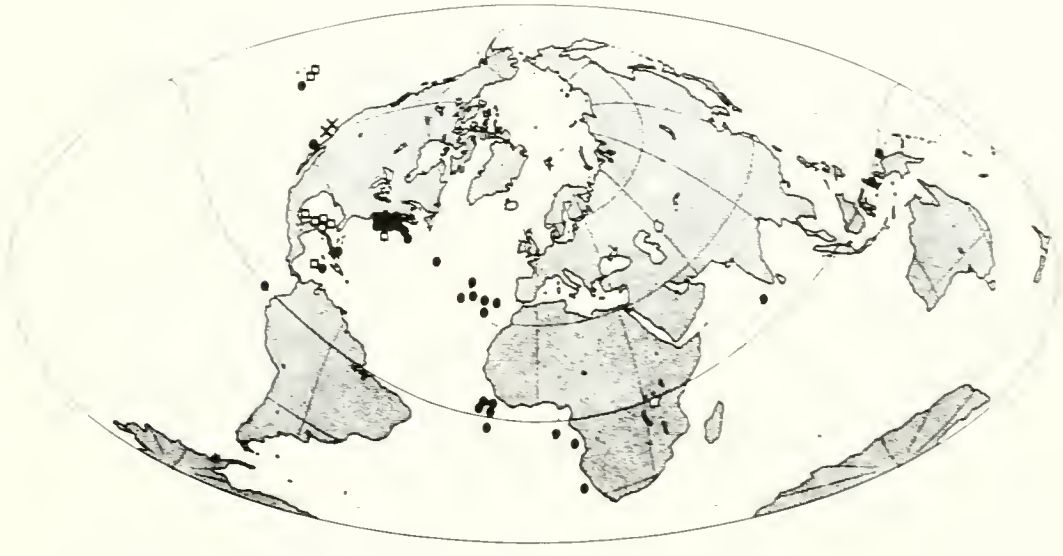

FIG. 4. *Distribution of* Alloposus mollis.

(200 mm and 67 mm in total length) and were taken at 70 m and 7 m depth respectively. According to Verrill (1881) the bathymetric range of the species extends to 2462 m depth, and fragments of specimens were taken from 3173 m depth. Berry (1914) states that it extends from 180 m to more than 900 m depth. Voss (1967) explains that Alloposidae appear to be distributed in the upper 400 m, although they may extend to more than 3000 m depth, and that larvae and juveniles occur in the upper 100 m.

Populations of *A. mollis* probably are stratified ontogenically, as is often the case in oceanic animals.

The temperature of the surface waters at the time of capture of our two specimens was 14.6°C (Specimen A), and 13.0°C (Specimen B), which is well within the range of temperature recorded for the species (Thore, 1949).

Cephalopods are important in the food web of the oceans, as they constitute the main food of dolphins, sperm whales, other sea mammals, turtles, Thunnidae, sharks and other large fish. Joubin (1895, 1900) found fragments of *A. mollis* (dorsal region and tentacular crown) in a region of the Atlantic where sperm whales were feeding, but found no *A. mollis* in their stomachs, possibly because of the difficulty in identifying digested gelatinous remains.

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VERTIGO MERAMECENSIS (PULMONATA: PUPILLIDAE) FROM THE NIAGARAN ESCARPMENT, IOWA

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ABSTRACT

The snail, Vertigo meramecensis *Van Devender was found at four localities along the Niagaran Escarpment in Fayette, Clayton, and Dubuque Counties, Iowa. Though more variable in morphology than originally reported, the species is easily distinguishable from* V. gouldi *with which it occurs. In Iowa,* V. meramecensis *inhabits steep, damp, well-forested talus slopes with extensive calcareous rock outcrops.*

Vertigo meramecensis was recently described from the Northern Ozark Plateau (Crawford County, Missouri) with sixteen individuals constituting the type series (Van Devender, 1979). Recent collecting in northeastern Iowa has turned up about fifty more individuals from four localities in Fayette, Clayton, and Dubuque Counties (Fig. 1). Two of these are drift collections but the species was collected alive at the two other sites (localities 3 and 4) in 1975 and 1979. Small litter samples were also taken in August, 1979 at both localities to insure adequate representation of all land snail species.

The Iowa collections materially enlarge the range of *V. meramecensis* and provide much additional information on the species' morphology and ecological requirements (discussed below). Van Devender's full description is confirmed in essentially all respects by our material. Though the species is closely related to the notoriously variable *V. gouldi gouldi* (Binney) (see Pilsbry, 1948), which is common in collections from all four localities, we encountered little difficulty in separating adult specimens of *meramecensis* from *gouldi,* even without recourse to a microscope or hand lens.

The Iowa localities are more than 300 miles to the north of the type locality. All four are situated on the Niagaran Escarpment of northeastern Iowa, a well dissected area with steep, heavily wooded bluffs unsuited for farming and with extensive outcrops of Silurian limestones and dolomites (Kankakee, Edgewood, and Hopkinton Formations). All are within a few miles of the Iowa portion of the Driftless Area, a region long known to harbor unusual land mollusks (Imlay, 1973). This portion of Iowa historically was among the most densely forested areas in a largely prairie state, and because of its rugged

FIG. 1. *Map of part of central United States showing known distribution of* Vertigo meramecensis *Van Devender.*

topography is probably the least disturbed by agriculture (Hartley, 1966).

Suitable habitat for *V. meramecensis* in Iowa is likely limited to the eastern third of the state and, possibly, the Loess Hills of extreme western Iowa. However, brief searches in the most nearly ecologically equivalent areas in Fremont, Boone, Linn, Johnson, and Lee Counties failed to produce any specimens, and many northeastern Iowa localities also lack the species. Although obviously much more work needs to be done on its distribution, it is probable that *V. meramecensis* will prove to be rare and very local in occurrence in Iowa, and confined to the northeastern corner. Until the range of *V. meramecensis* is better known some caution against overcollecting or other damage should be exercised. It would be particularly unfortunate if the type locality (subject to periodic flooding if the proposed Meramec dam were built, according to Van Devender, 1979) were lost.

Specimens used for this paper have been deposited in the collections of the Field Museum of Natural History (FMNH).

LOCALITIES

1. Drift at base of east-facing slope along Brush Creek, Brush Creek Canyon State Preserve, NE¼, NE¼, SE¼, SE¼, sec. 17, T92N, R7W, Wadena 7½′ quadrangle, Fairfield Twp., Fayette Co., Iowa.

2. Drift at base of north-facing bluff above Bear Creek, Bixby State Park, center SE¼, SE¼, SW¼, sec. 23, T91N, R5W, Edgewood 7½′ quadrangle, Lodomillo Twp., Clayton Co., Iowa.

3. Live collection and litter sample from dense upland woods on northwest-facing slope above a tributary to Bear Creek, S½, SE¼, SE¼, SW¼, sec. 23, T91N, R5W, Edgewood 7½′ quadrangle, Lodomillo Twp., Clayton Co., Iowa.

4. Live collection and litter sample from west-facing forested talus slope above Point Hollow Creek, White Pine Hollow State Preserve, NW¼, SW¼, NE¼, SE¼, sec. 7, T90N, R2W, New Vienna 7½′ quadrangle, Liberty Twp., Dubuque Co., Iowa.

DISCUSSION

Morphology: Our specimens range in length from 1.72 mm to 2.11 mm, slightly larger than Van Devender's but with a comparable mean length ($\bar{x}$ = 1.83). The observed widths (1.05 to 1.20 mm, $\bar{x}$ = 1.08) show an identical range but somewhat smaller mean ($\bar{x}$ = 1.10 for the Missouri specimens). Thus, Iowa specimens are quite similar to the type lot in dimensions but slightly more slender (mean H/D = 1.66 *vs.* 1.62 for the Missouri holotype). According to Van Devender (1979:71) half of the Crawford Co., Missouri, specimens lack a subcolumellar lamella. More than 90 percent of the Iowa material show some sign of a subcolumellar lamella, but this is usually vestigial (Figs. 2a-d). None have the subcolumellar as well-developed as the columellar; only one or two lack it completely. In most Iowa *V. meramecensis*, both palatals are equally recessed from the lip edge; nearly all have a knob-like lower palatal, and the long, slightly curved lower palatal present in 19 percent of the Missouri specimens characterizes a smaller percentage (<5 percent) of the Iowa specimens.

Although both *V. meramecensis* and *V. gouldi gouldi* are somewhat variable, mixed lots can be separated on several features. Van Devender (1979:72) emphasizes the smaller teeth and more open aperture of *V. meramecensis;* she also notes that the less massive and straighter parietal of *V. meramecensis* tends to point toward the lower palatal, while that of *V. gouldi gouldi* points between the two palatals. We have illustrated some examples of both species (compare Figs. 2a-d with 2e-h) in which these tendencies are less pronounced, but even the two most similar examples are clearly separable on apertural characters alone (Figs. 2k and l). Aside from the teeth, the aperture of *V. gouldi gouldi* is more elongate and the outer lip more strongly constricted.

Some differences in gross shell characters should also be mentioned. *V. meramecensis* has more evenly expanding, slightly shouldered whorls; associated *V. gouldi gouldi* tend to have

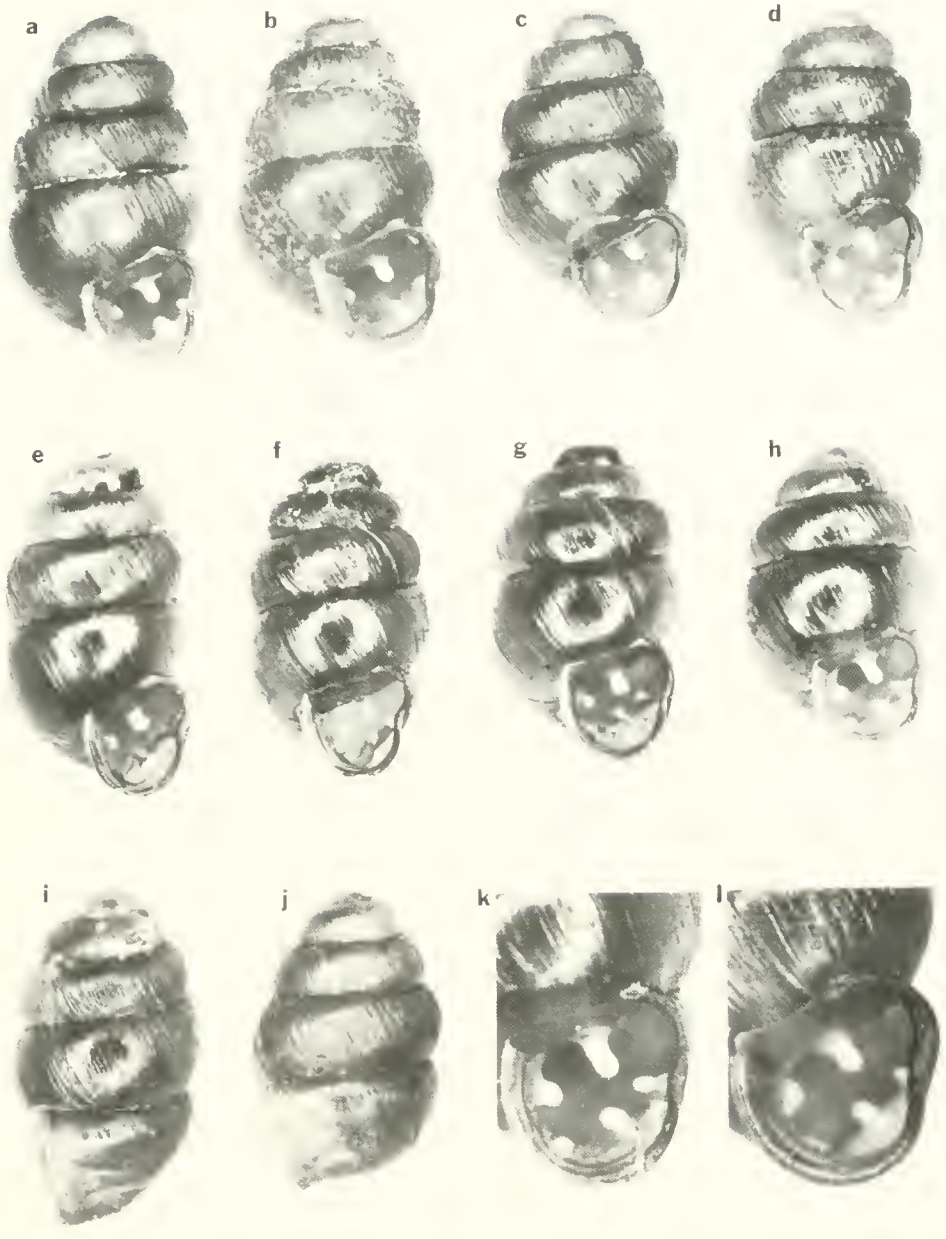

FIG. 2. Vertigo meramecensis *Van Devender (all deposited in the Field Museum of Natural History).* **a,** *Largest mature specimen, 2.11 mm. Dubuque Co., Ia.* **b,** Vertigo meramecensis *Van Devender. 2.05 mm. Clayton Co., Ia.* **c,** Vertigo meramecensis *Van Devender. 1.89 mm. Clayton Co., Ia.* **d,** Vertigo meramecensis *Van Devender. 1.89 mm. Clayton Co., Ia.* **e,** Vertigo gouldi gouldi *(Binney). 2.11 mm. Fayette Co., Ia.* **f,** Vertigo gouldi gouldi *(Binney). 1.94 mm. Fayette Co., Ia.* **g,** Vertigo gouldi gouldi *(Binney). 1.92 mm. Fayette Co., Ia.* **h,** Vertigo gouldi gouldi *(Binney). 1.82 mm. Fayette Co., Ia.* **i,** Vertigo gouldi gouldi *(Binney). 2.07 mm. Clayton Co., Ia.* **j,** Vertigo meramecensis *Van Devender. Dubuque Co., Ia.* **k,** Vertigo gouldi gouldi *(Binney). Enlargement of aperture. Fayette Co., Ia.* **l,** Vertigo meramecensis *Van Devender. Enlargement of aperture. Clayton Co., Ia.* **a-j,** *approximately 25×;* **k-l,** *approximately 45×.*

the ultimate and penultimate whorls about equal in width and more evenly rounded. Iowa specimens of both are not distinguishable on color (chestnut) and have equally sharply and regularly striate mature shell surfaces (Missouri *V. meramecensis* are more strongly and irregularly striate, according to Van Devender, *op. cit.*). Shells with mature apertures have between 3½ and 5 whorls.

Ecology: Both Iowa localities with live *V. meramecensis* are comparatively steep, protected lower slopes with deep, loamy soil and well developed litter interspersed with talus blocks of Niagaran dolomite. The forest is dominated by hard maples (*e.g., Acer saccharum*) and basswood, with common red oak, hickory, and dogwood. High slopes at Locality 4 also have common yew (*Taxus canadensis*) and white pine (*Pinus strobus*). Both support land snails (see Table 1), with *Carychium exiguum* most abundant. Both retain some mositure even in late August. Trees are more common and varied at the Clayton Co. locality; the slope at Locality 4 is less stable, more steep, and closer to the creek floodplain, hence moister. The majority of the species collected (slugs were not retained) are common to both (77 percent): those peculiar to one or the other (Locality 3: *Stenotrema fraternum, Discus patulus, Gastrocopta corticaria, Vertigo tridentata.* Locality 4: *Cochlicopa lubrica, Gastrocopta tappaniana, Striatura milium*) tend to support the observed differences in tree cover and moisture mentioned above. Both localities are good examples of habitat 7 of Thorne (1964:19), defined from the same area. Comparable slopes are situated in the immediate vicinity of Localities 1 and 2 also; these have not yet been litter sampled.

Land snails associated with *V. meramecensis* at the type locality are low in diversity (Table 1), very likely because the collection was made after dark on a limestone bluff; a litter sample was evidently not practical. Nevertheless, the general features (wooded limestone bluffs) appear comparable to Iowa occurrences. In summary, *V. meramecensis* seems to prefer rich, deep, moist, well-wooded slopes associated with extensive calcareous rock exposures.

Vertigo meramecensis is as yet unknown as a Pleistocene fossil. However, since many members of the *V. gouldi* complex do have fossil records (La Rocque, 1970; Browne & Bruder, 1968) it is possible that *V. meramecensis* has been overlooked. Few if any published faunal lists from Iowa or higher latitude Pleistocene sites contain faunas with species compositions like those of Localities 3 and 4, possibly because the climate was cooler in the summers than today. A distinctly boreal or Rocky Mountain land snail element is present in many northern loess faunas (Leonard & Frye, 1954).

In contrast the Iowa *V. meramecensis* sites contain a peculiar fauna combining predominantly northern elements *(Striatura milium,*

TABLE 1 Associates of V. meramecensis Van Devender.

Taxon	Crawford Co., Mo.	Locality 4 Dubuque Co., Ia.	Locality 3 Clayton Co., Ia.
Triodopsis albolabris (Say)	x	x	x
T. fosteri (Baker)	x		
Mesodon thyroidus (Say)	x	x	x
M. zaletus (Binney)	x		
Allogona profunda (Say)		x	x
Haplotrema concavum (Say)		x	x
Stenotrema barbatum (Clapp)		x	x
S. fraternum (Say)			x
Hendersonia occulta (Say)		x	x
Anguispira alternata (Say)	x	x	x
Discus patulus (Deshayes)			x
Cochlicopa lubrica (Müller)		x	
Zonitoides arboreus (Say)		x	x
Glyphalina indentata (Say)	x	x	x
Nesovitrea electrina (Gould)		x	x
Gastrocopta contracta (Say)		x	x
G. corticaria (Say)			x
G. holzingeri (Sterki)		x	x
G. pentodon (Say)		x	x
G. tappaniana (Adams)		x	
Columella edentula (Draparnaud)		x	x
Helicodiscus parallelus (Say)		x	x
H. singleyanus (Pilsbry)		x	x
Hawaiia minuscula (Binney)		x	x
Carychium exiguum (Say)		x	x
Striatura milium (Morse)		x	
Euconulus fulvus (Müller)		x	x
Strobilops labyrinthica (Say)		x	x
Punctum minutissimum (Lea)		x	x
Guppya sterkii (Dall)		x	x
Vertigo gouldi gouldi (Binney)		x	x
V. tridentata Wolf			x

TABLE 1. *Associates of* V. meramecensis *Van Devender.*

Hendersonia occulta) with predominantly southern elements here near the northern end of their range (*Discus patulus, Guppya sterkii*). Occurrence on the Niagaran Escarpment near or within the Driftless Area is not coincidental. Most *Hendersonia occulta* colonies occur within this region, as does the only reported colony of the definite Pleistocene relict *Discus macclintocki* (Hubricht, 1972). This type of fauna may have been widespread in the late Pleistocene in the southern United States, especially in Wisconsinan loesses associated with the Mississippi River. Hence, the most comparable fossil faunas are those of the Peoria Loess and ?Wisconsinan and younger talus deposits of eastern Missouri and adjacent Illinois, Kentucky, Tennessee, Mississippi, and Louisiana (*e.g.*, Hubricht, 1961, 1962, 1964a, 1964b; he also notes the unusual mix of normally disparate elements). These localities probably should be rechecked for *V. meramecensis*.

ACKNOWLEDGMENTS

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MEETINGS

50th AMU Anniversary Meetings in Florida 1981

Ft. Lauderdale, on the southeast coast of Florida, will be the site of the next annual meeting of the American Malacological Union to be held July 19–24, 1981. A special symposium, Functional Anatomy of Mollusca as Related to Higher Category Systematics, is being organized by President Richard S. Houbrick (Dept. of Invertebrate Zoology, National Museum of Natural History, Smithsonian Institution, Washington, D. C. 20560). Watch for further details about this special meeting which promises to draw malacologists from throughout the world.

1981 Western Society of Malacologists

The 14th Annual Meeting of the W. S. M. will be held at San Diego State University, San Diego, California, between June 23 and 26, 1981. The meeting will feature symposia and contributed papers on Molluscan topics, exhibits, shell and book auction, and field trips. All interested persons are invited to attend. For more information please contact Bruce Fowler, Secretary, 5512 Blossom Terrace Ct., San Jose, California 95124.

FEEDING AND FOOD PREFERENCES OF THE MURICID GASTROPOD *CERATOSTOMA FOLIATUM*

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ABSTRACT

Laboratory experiments and field observations of the carnivorous snail Ceratostoma foliatum *were used to determine whether or not a previously hypothesized dietary shift during ontogeny occurred and to examine the factors affecting prey choice. The hypothesized dietary shift from specialization on barnacles to generalization on bivalves did not occur. Both small (*≤50 mm) and large (>50 mm) C. foliatum *preyed largely on two bivalves species,* Adula californiensis *and* Protothaca staminea, *consistently choosing the latter even though it required drilling and yielded less energy per capture.* C. foliatum *apparently select* P. staminea *because they are less likely to be dislodged by rough waves while feeding.*

The gastropod *Ceratostoma foliatum* (Gmelin) is a common inhabitant of rocky shores along the northeast Pacific rim from Alaska to California. Despite its large size (>100 mm) and commoness its ecology is poorly known. Functional morphology (Spight and Lyons 1974, Palmer 1977) and life history patterns (Spight *et al.*, 1974) have been examined in some detail, but only a few feeding observations have been made. Spight *et al.* (1974) suggest that *C. foliatum* may follow a dietary strategy similar to that of *Muricanthus nigritus* (Philippi) (Paine 1966). Small *M. nigritus* are specialists on acorn barnacles while large individuals (>40–50 mm shell length) are generalists on gastropods. This dietary shift during ontogeny presumably occurs due to the increased energy demands of larger *M. nigritus* (Paine 1966). With *C. foliatum* the hypothesized dietary shift is from specialization on barnacles to generalization on bivalves. Based on the presumed adaptiveness of the labial spine on the outer lip of *C. foliatum*, Spight and Lyons (1974) suggest that the dietary shift should occur when the spine is functionally complete.

The purpose of this study is to examine two aspects of feeding in *C. foliatum*. First, what are the preferred prey, and what factors affect these preferences? Second, does a dietary shift occur during ontogeny when the labial spine becomes functionally complete?

MATERIALS AND METHODS

The study site was located along the southeast margin of Boiler Bay, Oregon. The area consists of scattered mudstone benches separated by surge channels. The stone is heavily perforated by boring organisms, principally bivalves in the families Pholadidae *(Nettastomella rostrata, Penitella penita* and *Zirfaea pilsbryi)* and Mytilidae *(Adula californiensis)*. Empty pholad burrows are inhabited by a variety of nestling species, including the bivalves, *Protothaca staminea* (Veneridae) and *Hiatella arctica* (Hiatellidae). Mussels *(Mytilus californianus)* and small acorn barnacles *(Balanus glandula)* are scattered over the study site. The density of potential prey was determined by a random quadrat method. A bench-mark was established in the center of the study site using a 2.5 cm diameter white plastic disc held in place with a 5.1 cm long masonry nail. A double set of random numbers was used to determine the north-south and east-west coordinates of each sample. Quadrats were 15×15 cm on the surface and

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rock was removed to a depth where no further boreholes were evident on the newly exposed rock surface. Snails found feeding during these searches were measured (shell length from apex to tip of siphonal canal) and the prey identified and measured. The method of attack was also noted.

The laboratory experiments were conducted in a 50×50 cm clear Plexiglas tank with constantly circulating 3.3% seawater. Water depth was maintained at 4 cm. During the study water temperature varied from 15–17°C. Eight snails, ranging from 31 to 69 mm shell length were placed in the tank and starved for seven days. Eight specimens of each of six prey species (i.e., *B. glandula*, *A. californiensis*, *M. californianus*, *N. rostrata*, *P. staminea*, and *Z. pilsbryi*) were then placed in the tank. Individual prey were placed randomly using a grid system and two sets of random numbers for determining coordinates. Specimens for each species represented the full size range available in the field. Prey items were replaced with another individual of the same species and size when eaten. The tank was covered during the experiment with black plastic. The experiment was checked at least every 12 hours. As with the field observations *C. foliatum* length, prey species, prey length and method of attack were recorded. Two prey species, *P. penita* and *H. arctica*, were not abundant enough to be used in the laboratory studies.

Caloric contents of the prey species were determined using a Parr oxygen bomb calorimeter (Anonymous, 1960). Prey were dried to a constant weight at 80°C, the dried tissues were removed from the shell and then tested according to the protocol in the Parr manual.

RESULTS

C. foliatum of all sizes use two different methods of attacking prey. Bivalves with an obvious siphonal gape (i.e., *A. californiensis*) were attacked by direct eversion of the proboscis through the gape. The siphonal region of the bivalve shells attacked in this manner showed no evidence of drilling activity, strongly suggesting that the radula and accessory boring organ were not used to enlarge the siphonal gape before proboscis eversion. Snails feeding in this manner had the head placed directly over the siphonal gape of the prey. The anterio-lateral corners of the propodium were extended anteriorly and medially to form a short tubular channel between the mouth and siphonal gape. The proboscis was extended through this channel. The labial spine was frequently observed pressed against the substrate to assure a firm purchase while feeding.

A different method of attack is used against prey such as *Protothaca staminea* which lacks a prominent siphonal gape. These prey were drilled through the valves, a mechanism widely used by muricid gastropods (see review by Carriker and Williams 1978). In the study area *P. staminea* normally occurs in empty *Penitella penita* burrows which have a small external opening and a spacious interior partially filled with sediment. *C. foliatum* feeding on these clams fold the lateral margins on the anterior half of the foot dorso-medially to form a tubular channel for the proboscis. This portion of the foot is everted through the burrow opening, and, once into the interior of the burrow it becomes greatly inflated (Fig. 1). Presumably

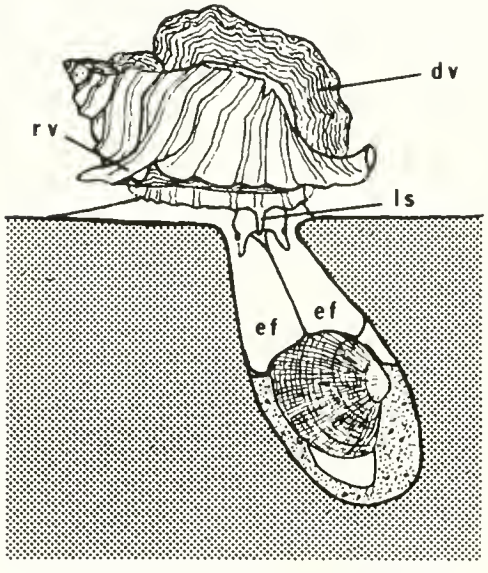

FIG. 1. Ceratostoma foliatum *edge-drilling a* Protothaca staminea *in an empty pholad burrow.* **ls,** *labial spine;* **rv,** *right varix;* **dv,** *dorsal varix;* **ef,** *everted portion of foot with right and left halves folded dorsally to form a tubular channel for the proboscis.*

the swelling is brought about by the transfer of body fluids into the extended portion of the foot. The anterior tip of the foot is attached to the prey, thus bringing the accessory boring organ and the radula (at the tip of the everted proboscis) close to the prey's valves. Of the clams attacked in this manner, 82% were drilled at the juncture of the valve edges where the shell is thinnest. The remaining 18% were drilled through one of the valves. The labial spine is not important in anchoring the snail to the substrate, since it is rarely pressed against the substrate as it is when *A californiensis* is being attacked. I have found *C. foliatum* harder to remove from the substrate when it is feeding on *P. staminea* rather than on *A. californiensis* simply because of the difficulty of pulling the swollen portion of the foot through the small burrow opening.

Spight and Lyons (1974) suggested that the diet of *C. foliatum* should shift at a shell length of 60 mm since at this size the labial spine becomes functionally complete. The *C. foliatum* at Boiler Bay reach a smaller size than those in Spight and Lyon's study. With the exception of a single, high-spired specimen of 82 mm, none of 168 individuals examined during the study exceeded 70 mm. The labial spine of Boiler Bay *C. foliatum* becomes functional when the shell reaches a length of about 50 mm. Because of this difference, I use 50 mm as the predicted size at which the dietary shift should occur in all the analyses which follow.

The results of the field feeding observations for small (≤50 mm) and large (>50 mm) *C. foliatum* for the period of April to August 1976 are compared using the chi-square test. Only those prey items eaten are listed in Table 1.

TABLE 1. *Field observations of feeding by small (≤50 mm) and large (>50 mm)* Ceratostoma foliatum. *Diets for the two size classes are compared using the chi-square test (x^2) and show no significant relationship between size and diet (x^2 = 2.33, p>0.05).*

C. foliatum size range	12 to 50 mm		51 to 70 mm	
Prey species	Number eaten	% Diet	Number eaten	% Diet
Adula californiensis	8	53	16	47
Hiatella arctica	1	7	0	0
Protothaca staminea	6	40	18	53

Other available prey are listed in Table 3. Diet is not related to size ($\chi^2 = 2.33$, p>0.05). A similar treatment for laboratory feedings also shows no significant relationship between size and diet ($\chi^2 = 1.39$, p>0.05; Table 2). A dietary shift does not occur when the labial spine becomes functional in *C. foliatum* from Boiler Bay.

TABLE 2. *Laboratory feeding observations for small (≤50 mm) and large (>50 mm)* Ceratostoma foliatum. *Diets are compared using the chi-square test and show no significant correlation between size and diet ($\chi^2 = 1.39$, p>0.05).*

C. foliatum size range	31 to 50 mm		51 to 69 mm	
Prey species	Number eaten	% Diet	Number eaten	% Diet
Adula californiensis	1	13	4	22
Mytilus californianus	0	0	2	11
Protothaca staminea	7	87	12	67

A number of prey characteristics may affect prey choice, although two, energy content (see review by Pyke *et al.* 1977) and abundance (Rapport 1971, Emlen 1973, Estabrook and Dunham 1976), are frequently considered to be the most important. The energy content of each prey species and the abundance of each species in both the field and laboratory observations are listed in Table 3. Only those species in families on which *C. foliatum* is known to prey are included in Table 3 (Spight *et al.* 1974, this paper). Because there was no relationship between size and diet within each set of observations the results were pooled (Table 3). The two most preferred prey *(P. staminea* and *A. californiensis)* are both high in energy content and common. But neither energy content nor abundance alone is an adequate predictor of preferred prey. The energetically most valuable prey *(A. californiensis)* only represented 21% of the laboratory diet, while *P. staminea* accounted for 71% of the laboratory diet. This preference for *P. staminea* is even more surprising, since *P. staminea* must be drilled before it can be eaten. Such drilling is not required for feeding on *A. californiensis.* In the field, *A. californiensis* and *P. staminea* each represent 49% of the diet. This change is presumably the result of *A. californiensis* being almost twice as common as *P. staminea* (Table 3). However, *N. rostrata,* which is also nearly twice as common as *P. staminea* was not eaten

TABLE 3. *Summary of prey characteristics and percent of diet in laboratory and field conditions. Since there is no significant difference between the diets of small and large snails in either the laboratory or the field the data have been combined within each treatment.*

		Laboratory		*Field*	
Prey species	Mean Energy content (Cal./ash-free g.)	Abundance (no./m²)	% Diet	Abundance (no./m²)	% Diet
Balanus glandula	--	32	0	11	0
Adula californiensis	4713	32	21	293	49
Hiatella arctica	--	--	--	9	2
Mytilus californianus	4596	32	8	0	0
Nettastomella rostrata	3918	32	0	276	0
Penitella penita	4161	--	--	9	0
Protothaca staminea	4560	32	71	151	49
Zirfaea pilsbryi	3714	32	0	98	0

even though *C. foliatum* has been observed feeding on other Pholadidae (Spight *et al.* 1974).

DISCUSSION

The labial spine appears to allow *C. foliatum* a greater purchase while feeding on certain prey, such as *Adula californiensis*, and possibly also during quiescent periods. A mature labial spine is clearly not needed to feed on bivalves, since small *C. foliatum* with poorly developed spines readily do so. Whether very small *C. foliatum* (about 10 mm or less), which lack a labial spine, can successfully attack bivalves is unknown. Such small snails are difficult to find in the complex environment at Boiler Bay.

The absence of the hypothesized dietary shift may be partially due to the time of the year of the study. Barnacle densities were particularly low at Boiler Bay while the field study was in progress (Table 3). Under such conditions specialization on barnacles may not be a viable alternative for small *C. foliatum*. Spight, *et al.* (1974) have found that *C. foliatum* responds to yearly fluctuations in barnacle density. When barnacles are abundant they are heavily preyed upon by *C. foliatum*. During lean years barnacles are infrequently eaten. Spight, *et al.* do not list the prey eaten when barnacles are rare, but the observations reported here suggest that *C. foliatum* of all sizes prey on bivalves when barnacles are unavailable.

Several factors affect prey selection. Energy content and abundance are important, since the two preferred prey (*P. staminea* and *A. californiensis*) are both common and energy rich, but do not adequately explain why *A. californiensis* is not more frequently eaten that it is. This mussel is the most abundant prey, has the highest energy content, and requires no preparatory drilling before ingestion. Yet *A. californiensis* is only eaten as frequently as *P. staminea* which is both lower in abundance and energy content and requires drilling prior to ingestion. One possible explanation for this paradox is the reduced risk to the snail of being dislodged. Feeding *C. foliatum* were frequently observed to be in more exposed positions than quiescent snails. Predators (Palmer 1977) or heavy surf (Menge 1978, pers. observ.) can readily remove exposed snails. Palmer (1977) has shown that the foliated varices of large *C. foliatum* significantly increases the probability that the snail will land with the aperture down, protecting the vulnerable foot from predatory fish. Palmer's results were obtained in still water, so it is unclear whether the same results would be obtained in surf. At Boiler Bay dislodged snails are frequently found being held upside down on the dorsal surface of the sea urchin *Strongylocentrotus purpuratus*. Normally this accounts for less than 1% of the *C. foliatum* observed, although after a storm as much as 11% of the population may be stranded on urchins (Kent, unpubl.). Stranded *C. foliatum* probably perish since they appear to lack any means of escape. Snails feeding in exposed positions would be most susceptible to being dislodged. The increased ability to remain attached while feeding

on *P. staminea* (due to the inflated foot) would reduce the risk of being dislodged and increase the "value" of *P. staminea* as a prey item. *A. californiensis* is more abundant and higher in energy content, but feeding on *A. californiensis* incurs greater risk of being dislodged by predators or heavy wave action.

The relative risks of being dislodged may also explain the concurrent development of the labial spine and the foliated varices in *C. foliatum*. In small *C. foliatum* the labial spine and varices are absent or poorly developed, but become increasingly well developed as the snail grows larger (Spight and Lyons 1974). At Boiler Bay small *C. foliatum* are most frequently observed in crevices and depressions where they would be relatively immune to disturbance by either predatory fish or surf. Larger *C. foliatum* have few refugia and are more exposed, particularly when feeding. Large varices would reduce fish predation but would increase the risk of being dislodged by surf (Palmer 1977). The labial spine conteracts this tendency by assuring a firm purchase to the substrate.

The labial spine of *C. foliatum* is not used for attacking new types of prey. Rather it functions as a handy tool for assuring a firm purchase while feeding in exposed positions. Where an even firmer purchase can be obtained by anchoring the foot in a burrow the labial spine is not used. At Boiler Bay the risk of being dislodged appears to be so high that prey preferences of *C. foliatum* have been affected.

ACKNOWLEDGMENTS

I wish to thank C. J. Bayne and J. C. Rutherford for helping during early stages of this work, J. L. Kent for assistance during the field work, and M. L. Reaka, E. M. Bird, and J. A. Veil for helpful discussions. I would like to thank G. J. Vermeij and T. M. Spight for their comments on this manuscript.

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A METHOD OF COLLECTING MINUTE LAND SNAILS

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East Tennessee State University
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ABSTRACT

A method is described which will facilitate the processing of leaf litter for dead shells of the Pupillidae and other molluscan micro-fauna by utilizing floatation of the shells against the different density gradients of water and xylene hydrocarbons. Most of the undamaged dead shells which were present in the original sample may be recovered by this process.

County and state records for the Pupillidae and other minute land snails indicate widely scattered distributions when compared to the reported ranges of the larger and more obvious land snails. This may be due to the difficulty encountered in processing large amounts of leaf litter for its molluscan micro-faunal content. The method of collection of minute land snails used by previous workers has largely been carried out by a process of sifting dried moss and leaf litter debris, followed by a laborious and time-consuming ordeal of hand-picking the residue (La Rocque, 1974; Smith, 1910; Sterki, 1887). Laver (1878) introduced the method of winnowing leaf litter in the wind, and thereby utilizing the force of the wind to carry away the unwanted debris. This method unfortunately introduces bias into the sample by the certain loss of such genera as *Punctum*, *Striatura*, and *Vertigo*. A more suitable means of separating the majority of the leaf litter debris involves the innovative addition of water floatation to the original process of dry sifting of leaf litter (Evans, 1972).

We have developed a method which will provide a maximum yield of molluscan shells with a minimum expenditure of time and effort. A leaf litter or moss sample is taken so as to include from 5 cm to 10 cm of soil. This will insure adequate sampling of the fine leaf/soil interface where many of the minute gastropods thrive. The contents of the sample should be placed on a screen having a 5-mm-square mesh which has been suspended over a deep bucket. The sample can then be gradually washed with water through the screen and into the bottom of the bucket. The fraction of sample which remains on the 5-mm screen should be searched for large land snails. Examination of the contents of the bucket after the initial washing phase will reveal a layer of detritus containing dead mollusk shells floating on the surface as a result of air trapped within their spires; the heavier fraction of soil and rock detritus will have settled to the bottom of the bucket. The floatant should be skimmed off the surface of the water and placed on a No. 60 mesh brass screen and allowed to drain. We have found it desirable to gently wash this fraction with tap water to remove the finest particles of floatant. The remaining fine detritus containing small mollusk shells should then be dried in an oven at about 60°C until the sample is completely dried. Forty-eight hours is usually sufficient drying time unless the sample contains a large amount of rotted wood or bog humus.

When thoroughly dry, the sample should be sifted into a beaker containing xylene and allowed to settle out for approximately one hour with periodic agitation until the fine debris stops falling to the bottom of the beaker. The remaining suspended floatant can then be skimmed off the surface of the liquid and placed on filter paper and allowed to drain dry at room temperature. When dry, this remaining fraction can be examined under a stereoscopic microscope or hand lens and the mollusk shells removed by touching a probe wetted with ethyl alcohol to the shells

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which will adhere to the probe. The shells may be collected in a vial of alcohol and subsequently dried at 60°C if desired.

A word of caution! Xylene has been determined to be a possible carcinogen; therefore, one should be sure that the work area is well ventilated and skin contact avoided as this substance may be absorbed through the skin with prolonged use. Other hydrocarbons such as toluene or benzene may be substituted providing the above precautions are adhered to.

Unfortunately, the above described floatation technique cannot be employed on clastic clay samples from Pleistocene cave deposits since the shells from these deposits are typically filled with clay. The following method has been found to yield satisfactory results for examining Pleistocene cave deposits for the molluscan micro-faunal contents. The sample is dried in an oven at 60°C until thoroughly dry, then it is covered with a hydrocarbon such as kerosene or varsol and allowed to stand overnight. After decanting the hydrocarbon, the sample is immediately covered with a mixture of boiling water and detergent and allowed to sit for a few hours. This will allow the clay to be broken up into finely particulate sediments thus preparing the sample for gentle washing through a 5 mm square mesh screen and into a collection bucket. After the contents of the sample remaining on the screen are examined, the fraction of sample collected in the bottom of the bucket is poured on to a No. 60 mesh brass screen and washed thoroughly with water. The fraction remaining on the No. 60 mesh brass screen is then dried in an oven at 60°C. The dried sample may then be examined under a stereoscopic microscope for molluscan content.

ACKNOWLEDGMENTS

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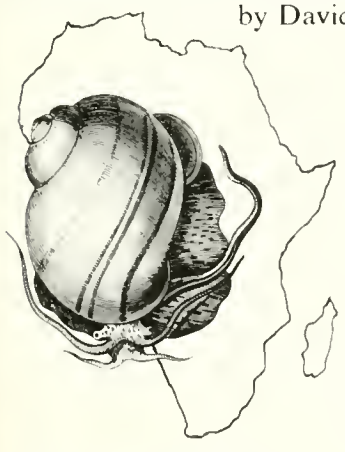

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Dr. David S. Brown is a senior scientist on the staff of the Medical Research Council of Great Britain and has been based for 20 years at the British Museum (Natural History) working with a team on research into host/parasite relations. During long periods of field-work in Africa, he has studied the entire gastropod fauna of fresh and brackish waters over large areas of the continent.

REVIEW

Brown, Davis S. 1980. *Freshwater Snails of Africa and their Medical Importance.* 487 pp., 153 pls. Taylor and Francis, Ltd., London. Distributed in the Americas by American Malacologists, Inc., P. O. Box 2255, Melbourne, FL 32901. Hardback, £25 in England, $55.00 U.S.

Dr. Brown's book on the "Freshwater Snails of Africa" is a welcome addition to regional faunal works of Africa, such as Pallary, 1909 (Egypt); Pilsbry and Bequaert, 1927 (Zaire, former Belgian Congo); Connolly, 1939 (South Africa); Mandahl-Barth, 1954 (Uganda); Wright, 1963 (Angola), and Brown, 1965 (Ethiopia).

The book begins with a systematic synopsis (Chapters 2, 3 and 4) of the Prosobranchia and the Basommatophora of the Euthyneura. The families and genera of African freshwater gastropods can be identified by means of keys (Chapter 2). The systematic synopsis includes distributional maps and information about ecology and parasites. Such essential information is presented for nearly 400 species, almost all illustrated in photographs or line drawings. Facts relevant to the study of biogeography are particularly difficult to segregate, and are found in many chapters. Investigators on snail biology and distribution have expended a great amount of effort in trying to explain the local distributions of particular snails in terms of physical and chemical limiting factors in the environment; some observations from the field and laboratory are summarized (Chapters 10 and 11). Chapter 12 deals with regional faunas and is an excellent feature of the book. For each zone there is a list of species encountered, with up-to-date nomenclature. These regions include North and Southern Africa, large lakes and major river basins. In addition to a subject index, there is a very useful taxonomic index. An Appendix includes methods used in studying snails.

This book is a must for those interested in the freshwater snails of Africa, their up-to-date systematic status, their geographic distribution, ecology, and their medical and economic importance.—*Emile A. Malik, Tulane University, New Orleans.*

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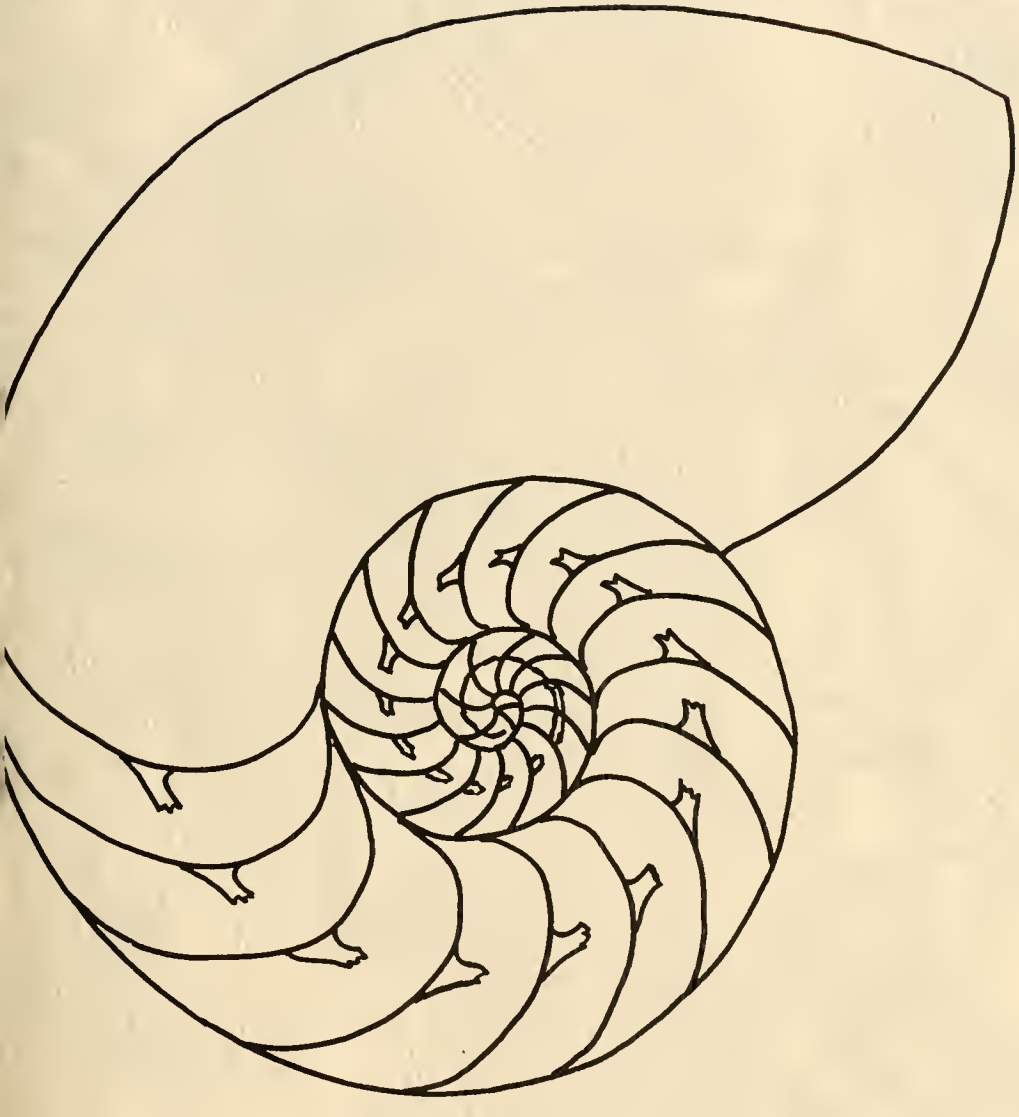

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OREOHELIX STRIGOSA COOPERI (BINNEY) IN THE MIDWEST PLEISTOCENE

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ABSTRACT

The pulmonate gastropod, Oreohelix strigosa cooperi *(Binney), occurs in the lower few feet of the Peoria Loess (Pleistocene: Wisconsinan) in a narrow band of localities from southwestern Iowa to western Illinois, disjunct by more than 340 miles east of the nearest modern occurrence. New localities include the westernmost and easternmost Pleistocene stations for the subspecies. The Peoria Loess is dated at 22,000 to 12,500 RCYBP, making the better-documented Pleistocene* O. s. cooperi *sites Woodfordian in age. Occurrence of* Oreohelix *and a distinctive associated molluscan faunule implies cooler and drier summers, and perhaps winters, and coniferous forest cover in part of the Peoria Loess outerop area.*

The genus *Oreohelix* is a characteristic element of the Rocky Mountain molluscan province (Henderson, 1931) and is frequently the only large land snail at many northern and central Rockies localities (Pilsbry, 1939). Its current distribution is centered in Idaho, Nevada, Wyoming, Montana, and Utah, but during Late Pleistocene one species ranged as far east as Illinois (Fig. 1). This subspecies, originally considered to be typical *Patula strigosa* Gould (McGee and Call, 1882: Keyes, 1888), was first relegated to the subspecific rank, *O. strigosa cooperi* Binney, by Shimek (1890). It was regarded as a distinct fossil subspecies *(iowensis)* by Pilsbry (1898 and 1916). He later relegated *O. strigosa iowensis* to the synonymy of *Oreohelix strigosa cooperi* (Binney), and considered these smaller fossils from Iowa and Illinois as similar to modern specimens (Pilsbry, 1939:445).

Literature records of varying value are available for several Iowa and Illinois counties. Our collections and museum collections substantiate some old records but others remain to be verified (Table 1). Most old localities cannot be recollected due to the ephemeral nature of many Pleistocene outcrops.

In the course of this study new county records for Mills and Linn Counties, Iowa and new localities in Polk and Johnson Counties, Iowa and Rock Island County, Illinois were accumulated. Recently collected material, as well as that from completely described old localities, apparently

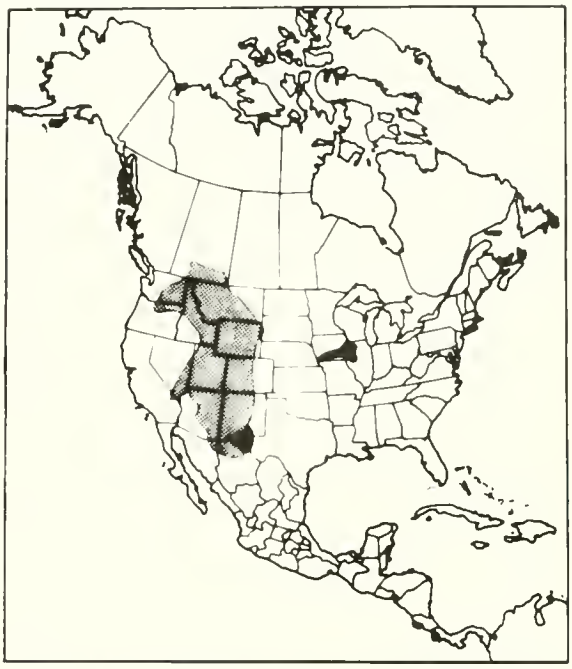

FIG. 1. *Map showing approximate recent (gray) and Pleistocene (black) distribution of* Oreohelix. *Recent distribution based on Pilsbry (1939, fig. 296,312), as modified by Bequaert and Miller (1973, fig. 4).*

TABLE 1. *Occurrence Data for* Oreohelix strigosa cooperi *(Binney). Starred localities have been collected by the authors.*

Locality	Source	Repository
ILLINOIS:		
Carroll Co.	Chamberlin & Salisbury (1888)	-----
Cass Co.	Leverett (1899)	-----
*Rock Island Co.	Morrison (1943)	NMNH, SUI
Whiteside Co.	McGee (1891)	
IOWA:		
Clayton Co.	Chamberlin & Salisbury (1888)	-----
Des Moines Co.	Leverett (1899)	-----
*Johnson Co.	Shimek (1888), Cameron (1940)	NMNH, ANSP, SUI, IMNH
Linn Co.	--------	SUI
Louisa Co.	Udden (1901)	-----
*Mills Co.	--------	SUI
Muscatine Co.	Udden (1899)	IMNH, NMNH
*Polk Co.	McGee & Call (1882), Keyes & Call (1892), Bain (1897)	NMNH, ANSP, SUI

occurs within a few feet of the base of the Peoria Loess. This formation was deposited between 22,000 and 12,500 RCYBP and can exceed 75 feet in thickness (Willman and Frye, 1970). Wood associated with *Oreohelix* at Locality 5–1a dates from 17,170±205 RCYBP.

At this locality and one other, *Oreohelix* is associated with abundant spruce macrofossils. This, together with the occurrence of *Oreohelix* as a member of a distinct faunule within the Peoria Loess, indicates a drier and much cooler climate during the Woodfordian for parts of Iowa and western Illinois. Peoria Loess *Oreohelix* apparently indicate a short-lived incursion of Rocky Mountain elements (and climates) into a limited area of the Midwest during the Woodfordian. The Midwest fossil localities are the only ones for *O. s. cooperi;* the easternmost occurrence of live specimens is in west central South Dakota, about 350 miles west of the nearest fossil occurrence (Mills County, Iowa).

All new material has been placed in the Repository, Department of Geology, The University of Iowa (specimens prefixed by the letters SUI). Old collections are at the U. S. National Museum of Natural History (NMNH), Academy of Natural Sciences of Philadelphia (ANSP), and The University of Iowa Museum of Natural History (IMNH).

LOCALITIES

In the course of this study *Oreohelix* was collected from several previously unrecorded sites in Illinois and Iowa, and one Illinois locality was successfully recollected (Morrison, 1943: Rock Island County). Provenance and location are summarized below.

1–1. Mills Co., Iowa. Giangreco local fauna. Alluvial channel fill associated with Peoria Loess, SE¼, NW¼, SW¼, SE¼, sec. 14, T71N, R43W, Mills Co., Iowa. Collected by junior author, 1972.

2–1. Polk Co., Iowa. Saylorville Reservoir section. Unoxidized Peoria Loess beneath Wisconsinan glacial till from Iowa Geological Survey drill hole, NE¼, NE¼, NW¼, sec. 20, T80N, R29W, Des Moines NW 7½′ quadrangle. *Oreohelix* and other snails associated with abundant wood and spruce needles. Collected by George Hallberg, 1976.

5–1. Johnson Co., Iowa. Conklin Quarry section. Peoria Loess above face of River Products Co. Conklin Quarry, Iowa City, NW¼, SE¼, SE¼, sec. 32, T80N, R6W, Iowa City West 7½′ quadrangle. *Oreohelix* from two sites (a) uncommonly in unoxidized basal Peoria swale fill on north facing slope above S. wall of quarry, associated with well preserved wood and spruce needles, seeds, some small mammals as well as other snails; wood date 17,170±205 RCYBP; and also in lower several feet of deoxidized loess overlying swale fill; (b) commonly in oxidized Peoria Loess on east facing slope above S. wall of quarry; at this site a barren deoxidized layer of coarse loess separates the fossiliferous unit from the underlying weathered till. Collected by authors and Leslie P. Fay, 1977–1979.

5–2. Johnson Co., Iowa. Iowa City Airport section. Peoria Loess in borrow pit NW of Iowa City Airport, NE corner, NW¼, SW¼, SW¼, sec. 16, T79N, R6W, Iowa City West 7½′ quadrangle. Collected by Leslie P. Fay and senior author, 1978.

5–3. Johnson Co., Iowa. Pentacrest Apartments section. Peoria Loess in excavation for Pentacrest Apartments, Burlington and Capital

Streets, Iowa City, SW¼, SE¼, SW¼, SW¼, sec. 10, T79N, R6W, Iowa City West 7½′ quadrangle. Collected by senior author, 1979; no longer exposed.

5–4. Johnson Co., Iowa. Lake MacBride section. Natural exposure of Peoria Loess along intermittent stream on N. side of N. arm of Lake MacBride, Lake MacBride State Park, center S½, SW¼, NW¼, sec. 29, T81N, R6W, Ely 7½′ quadrangle. Collected by authors, 1977 and 1978.

8–1. Rock Island Co., Illinois. Copperas Creek section. Peoria Loess in bank of Copperas Creek, SW¼, NW¼, NW¼, sec. 30, T16N, R6W, Blanchard Island 7½′ quadrangle. Same as Morrison (1943:104). Horberg's (1956:30) Locality 5 may also be the same locality: he gives a detailed section, most of which is no longer exposed, but did not find *Oreohelix*. Recollected in 1979 by Leslie P. Fay.

8–2. Rock Island Co., Illinois. Moline Airport East section. Peoria Loess exposed in borrow pit for Moline Airport, SW¼, NW¼, SW¼, NW¼, sec. 29, T17N, R1W, Milan 7½′ quadrangle. Collected by Leslie P. Fay, 1975.

8–3. Rock Island Co., Illinois. Coal Creek section. Peoria Loess exposed in Peterson Bros. Co. borrow pit along Coal Creek, NE¼, NW¼, NE¼, NW¼, sec. 27, T17N, R1W, Milan 7½′ quadrangle. Collected by Dr. Ann Foster and senior author, 1978 and 1979.

Because *O. s. cooperi* is generally quite rare, careful collecting is required to secure specimens. For example, processing of over 3,500 pounts of matrix from the Mills County site (Locality 1–1) yielded fewer than a dozen *Oreohelix*. Where possible each locality was visited several times: both hand and bulk collecting methods were used. Bulk samples weighed a minimum of one hundred pounds; generally several times that weight was collected, sieved, and picked for fossils.

DISTRIBUTION

Reported Pleistocene occurrences of *O. strigosa cooperi* are summarized in Table 1 and mapped on Fig. 2. Recent collecting has substantiated the presence of *O. s copperi* in Johnson and Polk Counties, Iowa, and in Rock

FIG. 2. *Map showing Midwest Pleistocene distribution of* Oreohelix strigosa cooperi *(Binney) by county. Large dots indicate areas from which specimens have been examined by the authors; small dots are unsubstantiated literature records.* Localities: Iowa–**1**, Mills Co.; **2**, Polk Co.; **3**, Clayton Co.; **4**, Linn Co.; **5**, Johnson Co.; **9**, Muscatine Co.; **10**, Louisa Co.; **11**, Des Moines Co.; Illinois–**6**, Carrol Co.; **7**, Whiteside Co.; **8**, Rock Island Co.; **12**, Cass Co.

Island County, Illinois, and has added Mills County, Iowa to the list. Museum collections are available for Rock Island County, Illinois, and for Johnson, Linn (previously collected but unpublished), Muscatine, and Polk Counties, Iowa. We have not been able to substantiate literature records for Carrol, Cass, and Whiteside Counties, Illinois, and for Louisa, Clayton, and Des Moines Counties, Iowa.

The unsubstantiated literature records vary in credibility. Carrol, Clayton, and Whiteside County specimens were identified by R. E. Call (Chamberlin and Salisbury, 1888:285, 286; McGee, 1891:448). The Des Moines County collection was made by Leverett and identified by C. T. Simpson (Leverett, 1899:169). B. Shimek provided the faunal lists for the Louisa County site (Udden, 1901:113). The Cass County record was based on specimens collected by J. F. Snyder and originally identified as *Helix solitaria* Say, *i.e.*, *Anguispira kochi* (Pfeiffer). Shimek (in Leverett, 1899:173) stated that these specimens probably were *O. s. cooperi* since *A. kochi* has not been found in Woodfordian sediments in Illinois (although present in Altonian and Farmdalian sediments farther south. Leonard and Frye (1960) thought Shimek's suggestion might be valid. On the other hand, Baker (1931:290) regarded all Illinois records as doubtful, since his collections from the same counties did not contain *Oreohelix*. Leonard and Frye (1960) also did not encounter the species in

central, western, or southern illinois. However, because *O. s. cooperi* is normally quite rare and hence easily overlooked, and because the chances of misidentification are slim, we tentatively accept all of the above records. A report of *O. s. cooperi* from Tazwell County, Illinois (Baker, 1922:58) is not plotted on Fig. 2 because it was based on fragments only and Baker later (1931:290) referred these to *Triodopsis multilineata wanlessi* (Baker).

Baker (1920, 1928) records *O. s. cooperi* in what he termed Yarmouth, Sangamon, and Peorian deposits. These stratigraphic assignments must be reevaluated because considerable refinement of Pleistocene stratigraphy has taken place since Baker's work. Nearly all well-documented Midwest *O. s. cooperi* occurrences are from the basal few feet of the Peoria Loess (as defined by Willman and Frye, 1970 in Illinois) or equivalents, and therefore Woodfordian in age. Possible exceptions are the Mills County specimens, which came from an alluvial channel probably associated with the Peoria Loess (and hence very likely Woodfordian), and some Muscatine specimens reported by Udden (1899:328) from a so-called "ante-glacial silt." This unit has not been restudied since Udden's work and as a result is of uncertain age. The Peoria Loess in Illinois spans the Woodfordian substange and dates from 22,000 to 12,500 RCYBP (Willman and Frye, 1970:125); in Iowa the largely equivalent "Wisconsinan" Loess is considered by Ruhe (1969:87) to date from 29,000 to 14,000 RCYBP.

As presently known, fossil *O. s. cooperi* occurs in a narrow band (average width: 30 mi.) stretching 340 miles from southwestern Iowa to eastern Iowa and western Illinois (Fig. 2). The species appears to be absent from the well-studied Peoria Loess of Nebraska and Kansas (Frankel, 1965; Leonard, 1952), Missouri (Pauken, 1969), Indiana (Johnson, 1965) and the Illinois and lower Mississippi River valleys in Illinois (Leonard and Frye, 1960). Living *Orcohelix* is endemic to the Rocky Mountain and Southwestern Molluscan Provinces; it is the dominant genus in the former (Bequaert and Miller, 1973). *O. strigosa* in one or another form occupies nearly the whole of the genus range (Fig. 1), *i.e.*, from eastern Washington, southeastern British Columbia and southern Alberta south through Montana, Wyoming, extreme western South Dakota and the west half of Colorado to New Mexico and northern Mexico. To the west it occurs in Arizona and southeastern Nevada north through Utah and Idaho. Modern *O. s. cooperi* occurs on the northeastern periphery of this range, in the Cypress Hills of Alberta and in the Black Hills of South Dakota (Pilsbry, 1939). This very limited distribution may be an artifact of spotty collecting. On the other hand the extant colonies could represent pre-glacial relicts (Taylor, 1965:606), *i.e.*, a form widely distributed prior to the Pleistocene whose range was reduced substantially during it. Alternatively, *O. s. cooperi* may be a recently evolved form adapted to a Pleistocene climate and surviving only in areas still retaining similar conditions as a glacial relict *(e.g.*, the Midwest endemic *Discus maeelintocki* (Baker), widespread in the Midwest Pleistocene but now restricted to an extremely limited area in northeastern Iowa (Hubricht, 1972)). The limited fossil record and present distribution of the genus argue against the last two possibilities. Other species presently limited to the Rocky Mountain Molluscan Province inhabited the Midwest during the Pleistocene, especially the Wisconsinan *(e.g., Discus shimeki, Columella alticola).* Moreover, although other Midwest endemics are now known to survive in northeastern Iowa, no relict populations of Rocky Mountain species have yet been encountered (Frest and Fay, *in prep.).* At its nearest point the Pleistocene range of the subspecies is disjunct some 340 miles from its modern range.

SHELL MORPHOLOGY

Although they are characteristically smaller, fossil specimens of *O. s. cooperi* agree very closely with Binney's original description (quoted in Pilsbry, 1939:443) based on recent shells. Measurements of the fifty largest specimens from Locality 4 show a considerable range in width and height (W max = 13.8 mm, W min = 10.3 mm, H max = 10.8 mm, H min = 6.5 mm; see also Fig. 3), but the means ($\overline{W}$ = 11.7 mm, $\overline{H}$ = 8.0 mm, $\overline{H}/\overline{W}$ = 0.68) are similar to Pilsbry's type of

O. c. iowensis (ANSP 10922: W = 11.4 mm, H = 7.7, H/W = 0.68). Large Recent specimens can exceed 20 mm in diameter. In a series from Lawrence County, South Dakota closely approaching the dimensions of fossil specimens the five largest have $\bar{W} = 15.5$ mm, $\bar{H} = 11.9$ mm, and $\bar{H}/\bar{W} = 0.77$. The umbilical width of both recent and fossil specimens is about one-fifth the shell diameter (Pilsbry, 1939:443–444).

Fossil specimens which retain original shell color generally have the two color bands characteristic of *Oreohelix* (Fig. 3b, e, h) but occasionally the upper band is faint or absent (Fig. 3q). The base frequently has one or more smaller bands (Fig. 3l, r); these also are sometimes faint or absent (Fig. 3f, o). The initial whorls are nearly smooth (Fig. 3c); later whorls have faint to moderate irregular transverse sculpture and subordinate spiral sculpture (Fig. 3a, d, g, j, m, p). Juveniles are sharply keeled and quite distinct from any other Peoria Loess snails. Mature specimens, fossil or modern, have the aperture strongly deflected and thickened. Fossil specimens are not as extreme in this regard as are some modern ones (compare Fig. 3q with Pilsbry, 1939: Fig. 279:34–36). Large fossil specimens have from 5 to 5½ whorls (Fig. 3p), as do many recent adults.

ECOLOGY

Relatively little recent ecological data is available for *Oreohelix*. Hendersen and Daniels (1916) found most species to be calciphiles; the commonest situation is in landslides or talus at the base of limestone cliffs (Henderson and Daniels, 1916; Pilsbry, 1939; Jones, 1940). These same authors note that it mostly occurs in widely scattered, locally dense colonies, a few feet or yards in diameter. We have collected or observed *Oreohelix (O. subrudis, O. pygmaea, O yavapai extremitatis, O. strigosa depressa)* in such situations in Wyoming and Alberta. In most cases colonies were clearly delimited by dead shells; commonly a wide scatter of very low density surrounds a much smaller area with numerous *Oreohelix*. Occasionally only a part of the area with common dead shells seemed to be currently occupied by living individuals. With proper rock or debris cover and calcereous soil, forest is not required by most *Oreohelix*, and the nature of the vegetation is irrelevant (Henderson and Daniels, 1916:317). *O. strigosa depressa* is found "indifferently under either rock or vegetative cover" (Henderson and Daniels, *op. cit.*) in colonies as described above. This form was collected by Hoff (1962) on the ground, in litter, and under rocks, mostly in mixed aspen, spruce, and fir stands in New Mexico. No specific information is available for *O. s. cooperi* other than that the South Dakota specimens were found in forest on limestone (Pilsbry, 1939:444), but its requirements are probably similar to those of *O. s. depressa.*

Pleistocene specimens are found in comparable situations. Though lacking rock cover, vegetated Peoria Loess would provide an adequately calcareous habitat for *Oreohelix* because it is generally quite calcareous where not subsequently leached; samples analyzed by Frye, Glass, and Willman (1962:49) averaged 9.15 percent CO_2, and X-ray analyses in Willman and Frye (1970:174–175) showed an average of 16 counts/sec. carbonate minerals in the <2u fraction, mostly dolomite. The subspecies is rare at most exposures, with only a few individuals being found (*e.g.*, Shimek (1989) collected a total of 85 specimens from all localities he visited). However, at one Johnson County site (Locality 4) over 365 *O. s. cooperi* were found. This situation seems analogous to the modern areal distribution; unless exposures were very extensive at a given locality one would expect to find dense colonies infrequently compared to the less rare occurrence of scattered individuals. Locality 5–1 exemplifies both situations: the colony at (b) provided most specimens (including all juveniles) while the two scattered occurrences at (a) together yielded fewer than a dozen specimens. Our other localities each had fewer than twelve *Oreohelix.*

Two dozen other land snail species are found with *O. s. cooperi* at our localities: the most frequent associates are listaed in Table 2. The fauna shows a mix of Holarctic and Nearctic elements, many of which are currently restricted to either the Northern or Rocky Mountain Molluscan Provinces in North America; others are

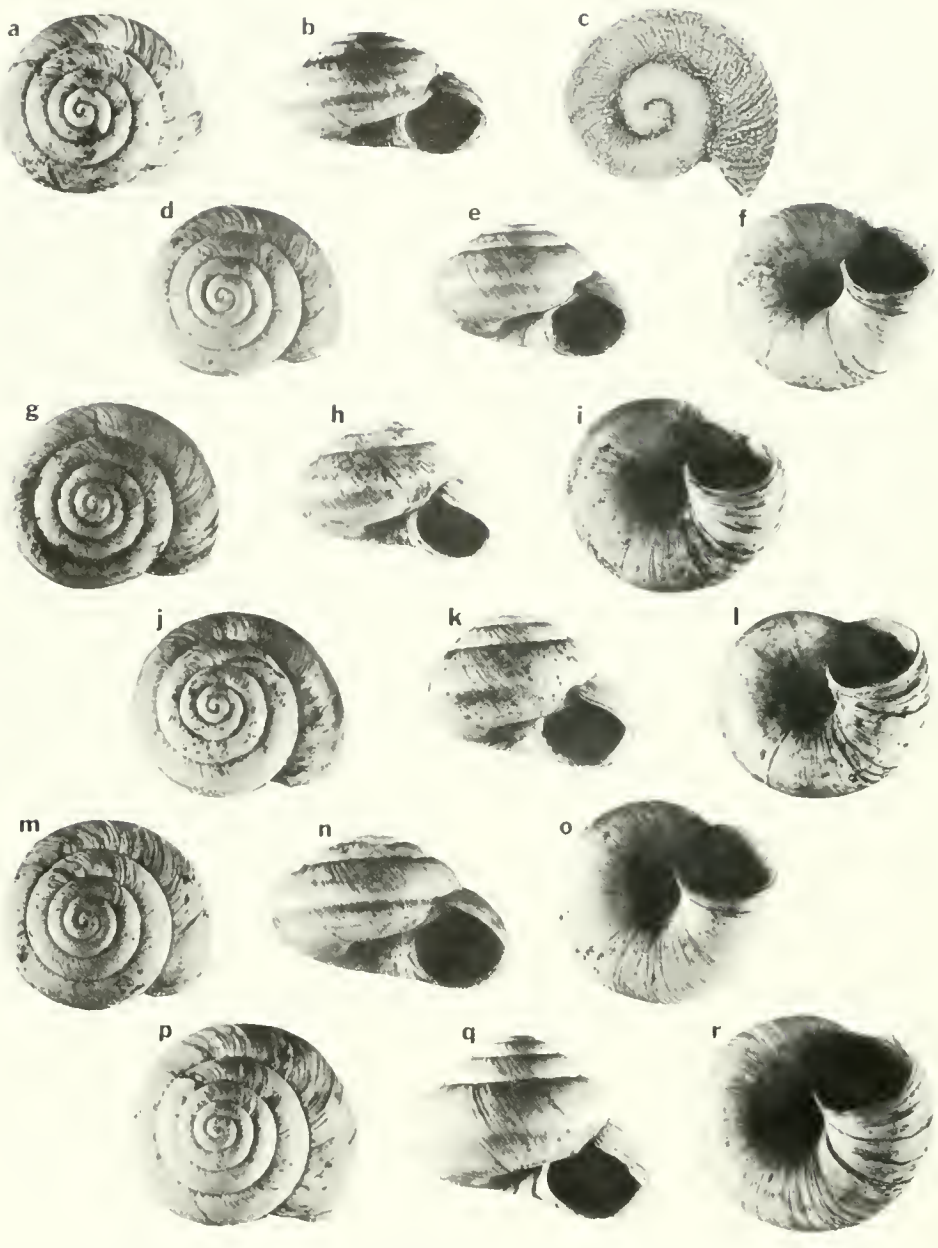

FIG. 3. Oreohelix strigosa cooperi, *Peoria Loess, Johnson County, Iowa; Locality 5-1b,* **a-b,** *SUI 49660, diameter=11.6 mm;* **c,** *SUI 49661, diameter=3.7 mm;* **d-f,** *SUI 49662, diameter=12.4 mm;* **g-i,** *SUI 49663, diameter=12.0 mm;* **j-l,** *SUI 49664, diameter=12.3 mm;* **m-o,** *SUI 49665, diameter=12.4 mm;* **p-r,** *SUI 49666, diameter=13.3 mm.*

so widely distributed as to be valueless as ecological indicators. Only two *(Hendersonia occulta, Triodopsis multilineata)* are Interior snails. There are no southern (Austroriparian) elements and only 60 percent of the associated species live currently in Iowa or Illinois; these

TABLE 2. *Common associates of* Oreohelix strigosa cooperi (Binney) in the Peoria Loess.

Taxon	Occurrence in Iowa-Illinois	Present Distribution	Distribution in Peoria Loess
Hendersonia occulta	X	Nearctic-Interior	widespread
Discus cronkheitei	X	Nearctic-widespread	widespread
Discus shimeki	-	Rocky Mts.	northern
Triodopsis multilineata	X	Nearctic-Interior	widespread
Cochlicopa lubrica	X	Holarctic-widespread	widespread
Succinea ovalis	X	Nearctic-widespread	widespread
S. grosvenori	X	Nearctic-widespread	widespread
Catinella gelida	X	Nearctic-widespread	widespread
Euconulus fulvus	X	Holarctic-widespread	widespread
Vallonia gracilicosta	-	Holarctic-Rocky Mts.	northern
Pupilla muscorum	-	Holarctic-Northern, Rocky Mts.	northern
Columella alticola	-	Nearctic-Rocky Mts.	widespread
Vertigo modesta	-	Holarctic-Northern	widespread
V. alpestris oughtoni	-	Holarctic-Northern	northern
Deroceras laeve	X	Holarctic-widespread	widespread

are mostly widespread and tolerant species.

Large snails are low in diversity and absolute numbers. Even if the Interior species are eliminated no modern fauna corresponds exactly to that associated with fossil *O. s. cooperi.* However, nearly all of the remainder do occur with modern *Oreohelix.* The most similar associations are those reported by Beetle (1954, 1957, 1961) from Wyoming, Karlin (1961) from Montana, Colorado, and New Mexico, and Hoff (1962) from New Mexico (with *Oreohelix* as a constituent) and by Wayne (1959) from northeastern Manitoba (without *Oreohelix).* Essentially all of the ecologically restricted species *(Discus shimeki, Vallonia gracilicosta, Pupilla muscorum, Columella altricola, Vertigo alpestris oughtoni, V. modesta)* are forms able to survive the cold, somewhat arid conditions of the high Rockies or northern Canada. None is restricted to forest, though most have been found in association with trees, especially coniferous forests. Karlin (1961) studied the relation of vegetation types to land snail distribution in Montana, Colorado, and New Mexico. Of the fifteen associations he discriminated, land snails were most abundant in pure aspen stands, mixed lodgepole pines and aspens, and mixed Englemann spruce-lodgepole pine-aspen forests (1961:61–62). Pure conifer forests commonly had few snails, although he assumes that "very small snail populations do exist in most coniferous woods" (1961: 65). Aspens especially would characterize burned or otherwise disturbed areas in largely spruce forests. Disturbance, and establishment of aspen, lodgepole pine, or mixed stands, leads to rapid local population increases for many land snail species *(op. cit.).* Except under the most favorable conditions of preservation, the numerically and areally dominant spruce would be the major plant macrofossil found in a deposit accumulated in an area with the cited plant associations. Karlin (1961:64) also found land snail abundance to be directly correlated with availability of free calcium.

At two localities in the Peoria Loess (5–1a and 2–1) *O. c. cooperi* occurred with abundant conifer wood and spruce needles: no plant macrofossils were preserved at the other localities. It can be inferred that Peoria Loess localities with *Oreohelix* had a climate with colder, drier summers (and possibly winters as well); the most likely vegetation would be spruce forest (with some aspen as the major deciduous component), possibly reduced to comparatively bare ground in areas nearest the ice margins. Our climatic interpretation is analogous to that suggested by Taylor (1965) for parts of the Wisconsinan Great Basin. He believes that the "cool-steppe fauna" of this region in the Early Wisconsinan indicates cooler summers, a lower mean annual temperature, and precipitation no greater (and possibly less) than at present (Taylor, 1965:603–604). However, this description applies to only a small part of the total Peoria Loess (Late Wisconsinan) outcrop area; more southerly locales with different land snail assemblages undoubtedly had a somewhat different climate and flora. Localities with *Oreohelix,* as noted above, have a distinctive fauna atypical of the Peoria Loess as a whole (see, *e.g.,* the lists of Leonard and Frye, 1960). It is very likely that much of the contro-

versy surrounding interpretation of Peoria Loess ecology (Shimek, 1930, 1931; Baker, 1928; Leonard and Frye, 1960; Taylor, 1965) results in part from failure to discriminate molluscan associations in fine enough detail (Frest and Fay, *in prep.)*. In any case, there is strong evidence that the most severe Pleistocene climatic changes in the Midwest occurred during the Wisconsinan (Taylor, 1965).

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SEASONAL METABOLISM OF THE SPHAERIID CLAM, *MUSCULIUM PARTUMEIUM,* FROM A PERMANENT AND A TEMPORARY POND

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ABSTRACT

Seasonal metabolic rates were examined for the sphaeriid clam, Musculium partumeium *(Say) from a permanent and a temporary pond. For the fall-born generation from the permanent pond and for the single generation from the temporary pond, metabolic rates peak during periods of greatest growth and reproduction. Metabolic rates were consistently higher for the permanent pond population. These rates for* Musculium partumeium *extend the available information on the family Sphaeriidae to the genus* Musculium.

One important aspect of the ecology of an organism is its seasonal pattern of metabolism. The majority of the investigations on the metabolic rates of freshwater molluscs have dealt with gastropods (Berg et al., 1962; Berg and Jonasson, 1965; Burky, 1971; Burky, Pacheco, and Pereyra, 1972; McMahon, 1973; Calow, 1976). Metabolic studies of sphaeriid clams have been limited. However, there are reported rates on *Pisidium* (Johnson and Brinkhurst, 1971b; Jonasson, 1972; Holopainen and Ranta, 1977a, b; Alimov, 1975; Burky and Burky, 1976) and *Sphaerium* (Alimov, 1975; Waite and Neufeld, 1977; Collins, 1967). The study of *Pisidium walkerii* by Burky and Burky (1976) is the only seasonal metabolic study in the literature. This study assessed the seasonal metabolic rates of the sphaeriid clam, *Musculium partumeium* (Say) from a permanent and a temporary pond.

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MATERIALS AND METHODS

Clams were collected from a temporary and a permanent pond in SW Ohio (see Way et al., 1980, for a description of the two ponds). The clams were sorted into 6–8 visual size categories (2–30 clams per chamber, depending on size) and oxygen consumption was measured monthly at field temperature with Clark-type 0_2 electrodes (YSI Model 53 moniter, YSI Model 5331 bath stirrer and chambers) using the acrylic chamber modification described by Burky (1977). After each experiment shell lengths (SL = greatest anterior-posterior dimension) were measured. Clams were dried to constant weight at 90°C, and they were subsequently analyzed for total nitrogen using a Coleman Model 29 nitrogen analyzer. Total dry weights were converted to tissue weights using shell correction values from Burky et al. (1979). Oxygen consumption values are expressed as $Qo_2 = \mu l$ 0_2/mg dry tissue/hr and $Qo_2 = \mu l$ $0_2/\mu g$ tissue N/hr. Tissue nitrogen can be assumed to represent protein and helps express the respiration rates in terms of more realistic energy equivalents.

RESULTS AND DISCUSSION

In order to consider seasonal metabolic rates it is necessary to briefly outline the life histories of the two populations (from Way et al., 1980). The ephemeral, or temporary, pond (DW) usually has a single generation per year. Clams are born (mean SL at birth = 1.4 mm) in the spring and early summer (May-July), remain dormant as juveniles in the dry substrate (August-January), begin growth in March (reaching adult SL of 5.9 to 10.1 mm in July), reproduce, and then die as the pond dries during the summer. The permanent pond (AM) has two generations per year. The first generation is born (mean SL at birth = 1.4 mm) in the spring between May and July (AM-SG). These individuals initiate growth during late August (reaching adult SL of 4.4 to 8.0 mm in November), and reproduce between September and November. Some adults of the spring generation overwinter and contribute to the next spring generation. Young of the fall, permanent pond, generation (AM-FG) overwinter as subadults (mean SL = 2.4 mm) and experience rapid growth and reproduction in late spring (reaching adult SL of 3.8 to 7.5 mm in July). Most clams of the fall generation die by the end of July, but a few survive to contribute to the new fall generation.

For *M. partumeium* there is no inverse relationship between metabolic rate and size within size series of adults or juveniles. Thus in the metabolic rate equation, $M = \mu l$ 0_2/clam/hr = kW^b, $b = 1$. In this study b was not significantly different from 1 for any date. Values of b not significantly different from one have been reported for gastropods (Daniels and Armitage, 1969; McMahon, 1973; and others), and for the sphaeriid clam *Pisidium walkerii* (Burky and Burky, 1976). It is also indicated in the data of Collins (1967) for *Sphaerium occidentale* and Johnson and Brinkhurst (1971b) on several genera of *Pisidium*. One possible explanation for the absence of a size-rate relationship is the small size range of clams within a particular generation. This idea is supported by the fact that for a number of dates where the size range of clams utilized was very small, the regression of log M on log tissue weight was not significant (prob. $F<0.05$). Burky and Burky (1976) discuss the possible effects of brooding young on b-value (sphaeriids are ovoviviparous) and the significance of a b-value of one on energy partitioning in *P. walkerii*. Consequently, oxygen expressed as μl 0_2/mg dry tissue/hr or μl $0_2/\mu g$ N/hr were averaged for all individuals, regardless of size, within a generation, i.e. all adult values were averaged on a given date as were values for juveniles.

Oxygen consumption for adults of the ephemeral pond (DW) population at field temperature (FT) ranges *from* 0.58 $\mu l 0_2$/mg tissue/hr, standard error (SE) = 0.04 (or 12.31 $\mu l 0_2/\mu g$ N/hr; SE = 0.46) for clams of mean SL = 7.57 mm in July (FT = 20°C) *to* 3.23 $\mu l 0_2$/mg tissue/hr, SE = 0.17 (or 22.65 $\mu l 0_2/\mu g$ N/hr; SE = 1.20) for clams of mean SL = 6.54 in May (FT = 14°C). Oxygen consumption averaged 2.29 $\mu l 0_2$/mg tissue/hr (or 12.81 $\mu l 0_2/\mu g$ N/hr) for newborns (May-July) at field temperatures of 14–20°C.

Values for adults of the permanent pond, spring generation, (AM-SG) range *from* 0.49 $\mu l 0_2$/mg tissue/hr, SE = 0.08 (or 4.39 $\mu l 0_2/\mu g$

N/hr, SE = 0.78) *to* 1.55 $\mu l0_2$/mg tissue/hr (or 14.14 $\mu l0_2/\mu g$ N/hr) for clams of mean SL = 6.34 in November (FT = 7.0°C) and for clams of mean SL = 5.97 in May (FT = 15°C) respectively. Newborns of AM-SG (mean SL = 1.4 mm) collected in August (FT = 20–25°C) average 2.18 $\mu l0_2$/mg tissue/hr (or 15.56 $\mu l0_2/\mu g$ N/hr). Permanent pond, fall generation (AM-FG) juveniles (mean SL = 3.16 mm) have metabolic rates averaging 1.64 $\mu l0_2$/mg tissue/hr (or 14.29 $\mu l0_2/\mu g$ N/hr) during November-May (FT = 7–15°C), while adults have rates ranging *from* 1.91 $\mu l0_2$/mg tissue/hr, SE = 0.75 (or 19.79 $\mu l0_2/\mu g$ N/hr, SE = 7.67) for clams of mean SL = 5.43 mm in July (FT = 20°C) *to* 3.36 $\mu l0_2$/mg tissue/hr, SE = 0.74 (or 35.35 $\mu l0_2/\mu g$ N/hr, SE = 8.34) for clams (mean SL = 5.35 mm) in June (FT = 18.5°C).

The comparable values reported in the literature are for the genus *Pisidium:* 0.35 to 0.87 $\mu l0_2$/mg tissue/hr at field temperatures for *P. walkerii* (Burky and Burky, 1976); 0.09, 0.15, and 0.33 $\mu l0_2$/mg tissue/hr at 11°C, 16°C, and 8°C for *P. casertanum* (Berg et al., 1962; Berg and Jonasson, 1965); and 0.43, 1.08, 1.15, and 1.30 $\mu l0_2$/mg tissue/hr at 20°C for *P. casertanum, P. ventricosum, P. henslowanum,* and *P. casertanum,* respectively (calculated using a 0.5 mg standard clam for Johnson and Brinkhurst, 1971b). Values for other sphaeriids have been reported by Collins (1967), Alimov (1975), and Waite and Neufeld (1977), but oxygen consumption is expressed per tissue wet weight or total wet weight (including shell) and thus are not comparable.

Oxygen consumption for the fall generation at the permanent pond (AM) rapidly increases during the months of April and May (2.33 to 4.15 $\mu l0_2$/mg tissue/hr), corresponding to the period of peak growth and reproduction, with a subsequent decline over the summer months (4.15 $\mu l0_2$/mg tissue/hr in May to 1.91 $\mu l0_2$mg tissue/hr in late July). Patterns of growth and reproduction for overwintering clams at the ephermal pond (DW) are similar to those of the permanent, fall generation (AM-FG) (Way et al., 1980; Hornbach et al., 1980). Therefore it is not surprising that the annual patterns of respiration of overwintering ephemeral pond (DW) clams are very similar when compared to the permanent pond ones (AM-FG). Rates increase from April to May (1.42 to 3.23 $\mu l0_2$/mg tissue/hr) and then decrease from May to July (3.23 to 0.58 $\mu l0_2$/mg tissue/hr) when the pond dries. The annual respiratory pattern is the same for ephemeral (DW) and permanent (AM-FG) pond generations when the values are based on tissue nitrogen, but oxygen consumption rates are consistently higher for the latter. Clams of the permanent pond (AM-FG) partition more of the total assimilated energy to respiration than do those of the ephemeral pond (DW) (56% vs. 38% for AM-FG and DW, respectively; Burky, Hornbach and Way, unpublished data), thus ephemeral pond (DW) clams can direct a greater fraction of the total assimilated energy to growth and reproduction.

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TAXONOMIC RE-EVALUATION OF THE BIVALVE FAMILY LYONSIIDAE[1]

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ABSTRACT

The taxonomy of the marine lyonsiid bivalves is reviewed and redefinitions of the family and genera are offered. These lyonsiids are divisible into three distinct genera, Lyonsia, Entodesma, *and* Mytilimera, *based primarily upon periostracum and calcareous shell structure, umbonal length ratios, modifications of the mantle edge including the presence of arenophilic radial mantle glands, morphology of the pedal gape, comparative sizes of adductor muscles, morphology and size of the foot and byssal systems, modifications of the siphons and general habitats. Some changes in generic taxonomy are suggested. It is also recommended that the present subgeneric taxa for the marine Lyonsiidae be abandoned since these lower ranks indicate ecomorphs and not true taxonomic units.*

Few modern workers have concerned themselves with the systematics of the bivalve subclass Anomalodesmata. Existing reports are conflicting and have thrown the taxonomy of this heterogeneous group into a state of confusion and disarray. The subclass contains such diverse members as the elongated and cylindrical clavagellid watering-pot shells, the

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laterally compressed pandorids and the "carnivorous" septibranchs.

The Lyonsiidae are also members of this poorly understood subclass. This family, comprising some 20 (Boss, 1971) to 45 species, exhibits characteristics which easily distinguish the group. The subfamilial taxonomy is less precise. Several different versions of lyonsiid taxonomy place from one to twelve extant genera in the family. Some recent authors (Abbott, 1974; Narchi. 1968; Prezant, 1979a) place three genera in the Lyonsiidae: *Lyonsia, Entodesma,* and *Mytilimeria.* Habe (1977) puts four genera in the lyonsiids of Japan *(Lyonsia, Allograma, Bentholyonsia* and *Agriodesma),* and Keen (1969), five genera in the family *(Lyonsia, Allograma, Entodesma, Mytilimeria* and *Ostomya).* Habe first introduced *Bentholyonsia* as a subgenus (1952), then (1977) elevated it to generic status. The characteristics distinguishing this genus from *Lyonsia* are obscure. Morrison (1943) described a new genus and species of lyonsiid, *Guianadesma sinuosum,* from freshwater rivers of Guyana. This species, according to Morrison, is the only lyonsiid known to lack an internal calcareous ossicle, the lithodesma, which divides the resilium into two portions. *G. sinuosum* has many other lyonsiid characteristics in soft parts and shell (overall shell shape, edentulous hinge, fused mantle lobes), but the exact classification must remain tentative until the internal morphology and shell microstructure have been more critically examined. Yonge (1952) felt that Lyonsiidae should include *Agriodesma* and the three genera advocated by Abbott (1974). Thiele (1935) classified *Agriodesma* and *Entodesma* as subgenera of *Lyonsia* while Dall (1903) placed *Entodesma* and *Lyonsia* s.s. as subgenera of *Lyonsia,* and *Allograma* and *Philippina* as sections of *Entodesma.* According to Lamy (1928), the only valid genus in the family is *Lyonsia,* with *Entodesma, Agriodesma,* and *Allograma* being subgenera. Vokes (1980) has listed ten recent, genera in the family: *Agriodesma, Allograma, Anticorbula, Bentholyonsia, Entodesma, Guianadesma, Lyonsia, Mytilimeria, Philippina,* and *Phlycticoncha.*

Increased data on soft part morphology, behavior, and paleontology accumulated since the earlier studies have left us with more data on which to draw for taxonomic interpretations. Many early bivalve taxonomic systems were based on a single or very few characteristics, such as fusion of mantle lobes (Duméril, 1806; Fleming, 1822; Latreille, 1825), shell symmetry and pallial sinus (Linnaeus, 1758; Orbigny, 1843), pedal system (Gray, 1847; Lankester, 1883), adductor muscles (Philippi, 1853), gills (Fischer, 1886; Pelseneer, 1889; Ridewood, 1903), hinge system (Neumayr, 1884; Dall, 1895), and type of stomach (Purchon, 1959). Dall (1895, 1913) and Douvillé (1896, 1912, 1913), and later Cox (1960) and Newell (1965), promoted total organism taxonomy with correlating evidence, as available, from paleontology. For many taxa, sufficient data are now available to permit us to follow this holistic approach in classifying mollusks based on distinct characteristics of the entire animal.

Recent work on the mantle edge and shell of the Lyonsiidae (Prezant, 1980; 1981) required a corresponding examination of the morphology and behavior of numerous members of this family and has prompted this re-evaluation of the group's higher taxonomy.

Institutional Abbreviations

ANSP–Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania
CAS–California Academy of Sciences, San Francisco, California
LAMN–Los Angeles County Museum of Natural History, Los Angeles, California
MCZ–Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts
NMNH–National Museum of Natural History, Smithsonian Institution, Washington, D.C.

METHODS AND MATERIALS

Lyonsia floridana, L. hyalina, L. californica, Entodesma saxicola and *Mytilimeria nuttalli* were collected live and observed in the laboratory on a running seawater table at 12°–18°C at 30 ppt salinity. Individuals of the genus *Lyonsia* were placed on a sterile, fine sand substratum. *L. floridana* were originally collected from

Blind Pass, Sanibel Island, Florida, in shallow waters in a fine-to medium-grained sand and shell substratum. *L. hyalina* were collected from depths of 14–20 meters in Nahant Bay, Massachusetts, and Delaware Bay, Delaware, in fine sands. Living specimens of *L. californica* and *M. nuttalli* were collected from along the coastline of Venice, California. Specimens of live *E. saxicola* were collected just subtidally on Shaw Island, Washington.

Museum specimens included: *Lyonsia gouldii* (MCZ), *L. californica* (LAMN), *L. pugetensis* (NMNH), *Entodesma beana* (NMNH), *E. cuneata* (ANSP), *E. patagonica* (ANSP, NMNH), *E. saxicola* (CAS), *E. truncatissima* (ANSP), and *Mytilimeria nuttalli* (CAS). Specimens of *E. fretalis* and *E. chilensis*, both found among the colonial tunicate *Pyura chilensis*, were obtained from Corral Bay, Chile. These were fixed in Zenker's fluid or 10% formalin prior to observations.

Measurements were taken to the nearest 0.5 mm with a pair of Mitutoya calipers. Umbonal length ratio measurements are defined as the ratio of the longitudinal distance from the umbo to the anteriormost part of the shell to the horizontal distance from the umbo to the posteriormost part of the shell. Histological and electron microscopical techniques are described in detail elsewhere (Prezant, 1979a, b, 1980). In brief, specimens were fixed in Zenker's fluid or 10% formalin, embedded in polyester wax, sectioned at 5–10 μm and stained with Heidenhain's or Groat's hematoxylin and eosin or a modification of the Pantin trichrome (Prezant, 1979a). For scanning elctron microscopy, shells were dried in ethanol or critically point dried, coated with a thin layer of carbon and gold and examined at accelerating voltages to 15–30 k V in a Philips PSEM 501.

RESULTS

The family Lyonsiidae is composed of three valid marine genera: *Lyonsia*, *Entodesma*, and *Mytilimeria*. Species within the genus *Lyonsia* are usually found vertically oriented and partially buried in fine sands or muds with their posterior fifth to third exposed above the substratum. This intertidal to deeply benthic genus has an active foot but produces only a few weak byssal threads to aid in attachment and stabilization. Further stability within the substratum is obtained by adhesion of foreign particles, often forming a dense coat over the periostracum which adds to the surface area and weight of the bivalve (Prezant, 1979a, b, 1980). Ansell (1967) described the burrowing activities of *L. norwegica* (Gmelin) as very slow. Stanley (1970) concluded the same for *L. hyalina*. Observations of *L. californica*, *hyalina* and *floridana* in the present study showed that these bivalves burrowed to their usual partially buried position within two to four minutes. They often traversed short distances while in the substratum, as revealed by numerous trails left in the sediment. All three species showed photosensitivity and responded to shadows by withdrawing their siphons and adducting their valves.

Species of the more sedentary genus, *Entodesma*, are usually found intertidally or just subtidally, nestled within rocky crevices or among algal holdfasts, tunicates or sponges. The genus possesses the largest individuals of the family and also the thickest shelled members. *Entodesma*, especially as juveniles, can adhere foreign particles to their shell but, unlike *Lyonsia*, are attached by numerous, thick and strong byssal threads. The nestling habit of these bivalves often produces distorted shells reflecting compressions or modifications of growth within their, often small, rocky crevices. This habit results in great variability in shell shape of individuals in a given species, and makes shell form a difficult characteristic to use in species determination.

The third lyonsiid genus, composed of a single known species, *Mytilimeria nuttalli*, has assumed a totally sessile life-style embedded within compound tunicates *(Eudistoma psammion* and *Distaplia occidentalis)* usually in the intertidal zone, although Smith and Gordon (1948) report finding this bivalve in depths of about 20 meters. The larvae of *M. nuttalli* initially settle upon and are eventually encased by the growing ascidian colony (Yonge, 1952). The clams maintain a narrow siphonal slit in the ascidian test that is forced apart by protrusion of their siphons and seals tightly when the siphons

	LYONSIA	ENTODESMA	MYTILIMERIA
HABITAT	intertidal to deep benthic; partially buried in fine sands or muds	intertidal to subtidal; usually nestled in rocky crevices or among algal holdfasts, tunicates or sponges	intertidal to just subtidal; embedded within compound ascidians
PERIDSTRACUM	thin radially spinulated; often sand covered; radial striae	thick, wrinkled; may have partial extraneous cover; radial striae	thin; golden brown; surface pitted with crater-like pores
SHELL	elongate with less than 1:2.5 umbonal length ratio; thin prismatic, biphasic nacre	elongate with greater than 1:2.5 umbonal length ratio; often a thick homogeneous layer; always a thin prismatic and biphasic nacre	globular shell with less than 1:2.5 umbonal length ratio; thin homogeneous, thick prismatic, biphasic nacre
MANTLE	thin, non-muscular edge with numerous multicellular mantle glands opening into periostracal groove	thick, muscular mantle edge with many mantle glands as juvenile that open distal to periostracal groove	muscular, deeply pigmented mantle edge; no arenophilic radial mantle glands
ADDUCTORS	isomyarian to slightly heteromyarian	slightly heteromyarian	heteromyarian
FOOT AND BYSSAL SYSTEM	active foot is long and laterally flattened; well developed byssal gland produces a few, thin byssi; pedal gape long and narrow with no internal rim	small, cylindrical foot; well developed byssal gland produces many thick byssi; pedal aperture is circular and has a raised internal rim	small cylindrical foot; poorly developed byssal gland produces a few, thin byssal threads; small, circular pedal gape
SIPHONS	narrow lumens; numerous, small variously colored, pigmented spots; numerous small photoreceptors on exhalent siphon	very muscular with medium diameter lumens; no photoreceptors	very broad siphonal lumens; no photoreceptors

TABLE 1. *Comparison of the major generic differences within the family Lyonsiidae.*

Lyonsia arenosa Möller, 1842	1:1.9
Lyonsia californica Conrad, 1837	1:2.1
Lyonsia floridana Conrad, 1849	1:1.9
Lyonsia gouldii Dall, 1915	1:1.3
Lyonsia hyalina Conrad, 1831	1:1.5
Lyonsia norwegica Gmelin, 1791	1:1.6
Lyonsia pugetensis Dall, 1913	1:1.5
Entodesma beana (Orbigny, 1842)	1:5.9
Entodesma chilensis (Philippe, 1845)	1:6.7
Entodesma cuneata (Gray, 1828)	1:4.8
Entodesma fretalis (Dall, 1915)	1:4.7
Entodesma patagonica (Orbigny, 1846)	1:3.8
Entodesma saxicola Baird, 1863	1:2.8
Entodesma truncatissima Pilsbury, 1865	1:4.6
Mytilimeria nuttalli Conrad, 1837	1:1.6

TABLE 2. *Average ratio of distance from umbo to anterior shell edge and posterior shell edge to umbo. Higher ratios mean greater distance from umbo to posterior edge than from umbo to anterior edge of shell. Measurements exclude any overlap of periostracum at the shell edge.*

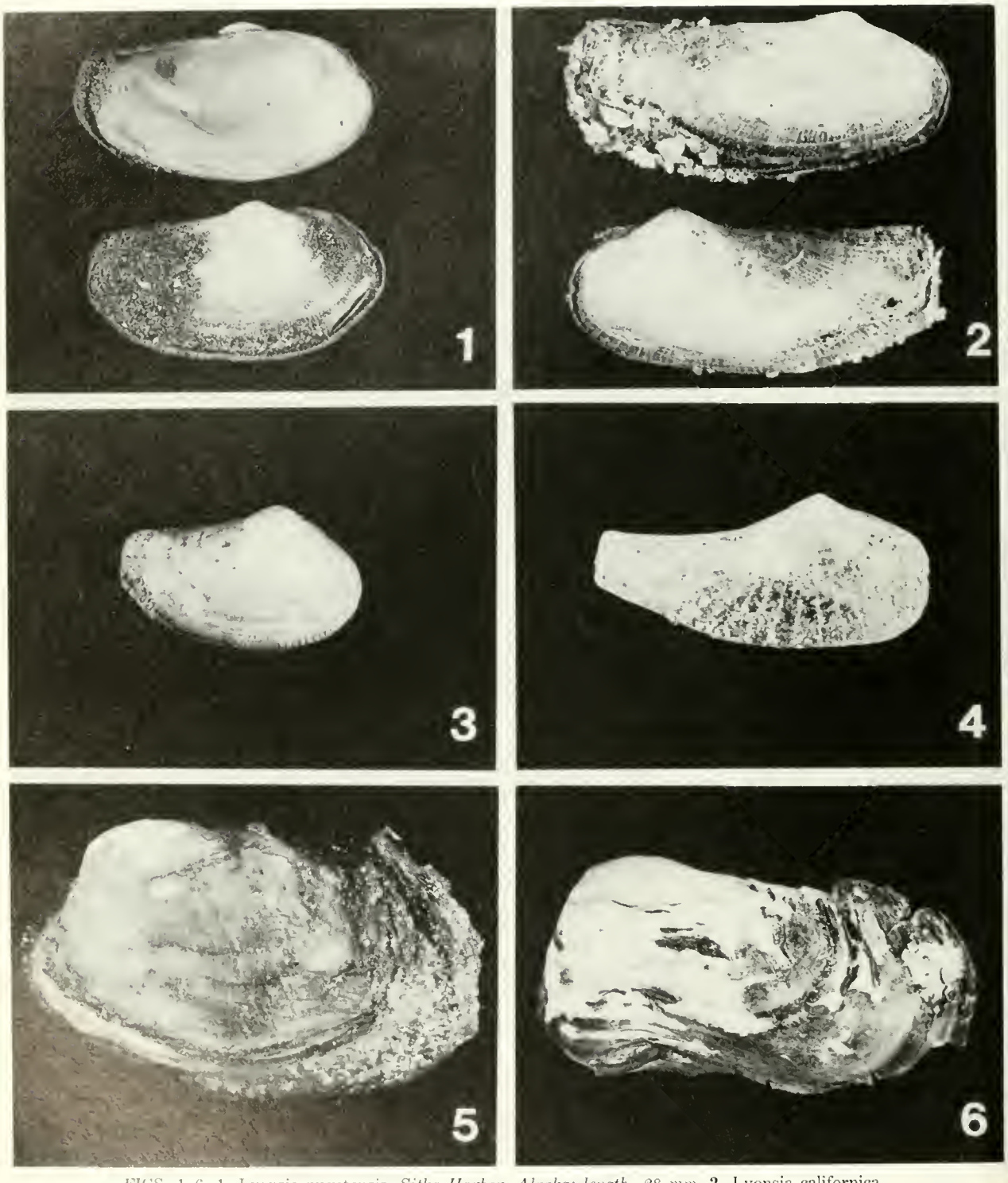
are withdrawn. *Mytilimeria nuttalli*, as a juvenile (Yonge, 1952) and when removed from its host as an adult, can produce a few thin, weak byssal threads. Based upon the globular shell shape, this species appears the least lyonsiid like, but shell ultrastructure and internal anatomy reveal that it is indeed a member of the Lyonsiidae.

Detailed morphological differences between the three genera of Lyonsiidae are noted in the following definitions and in Tables 1 and 2.

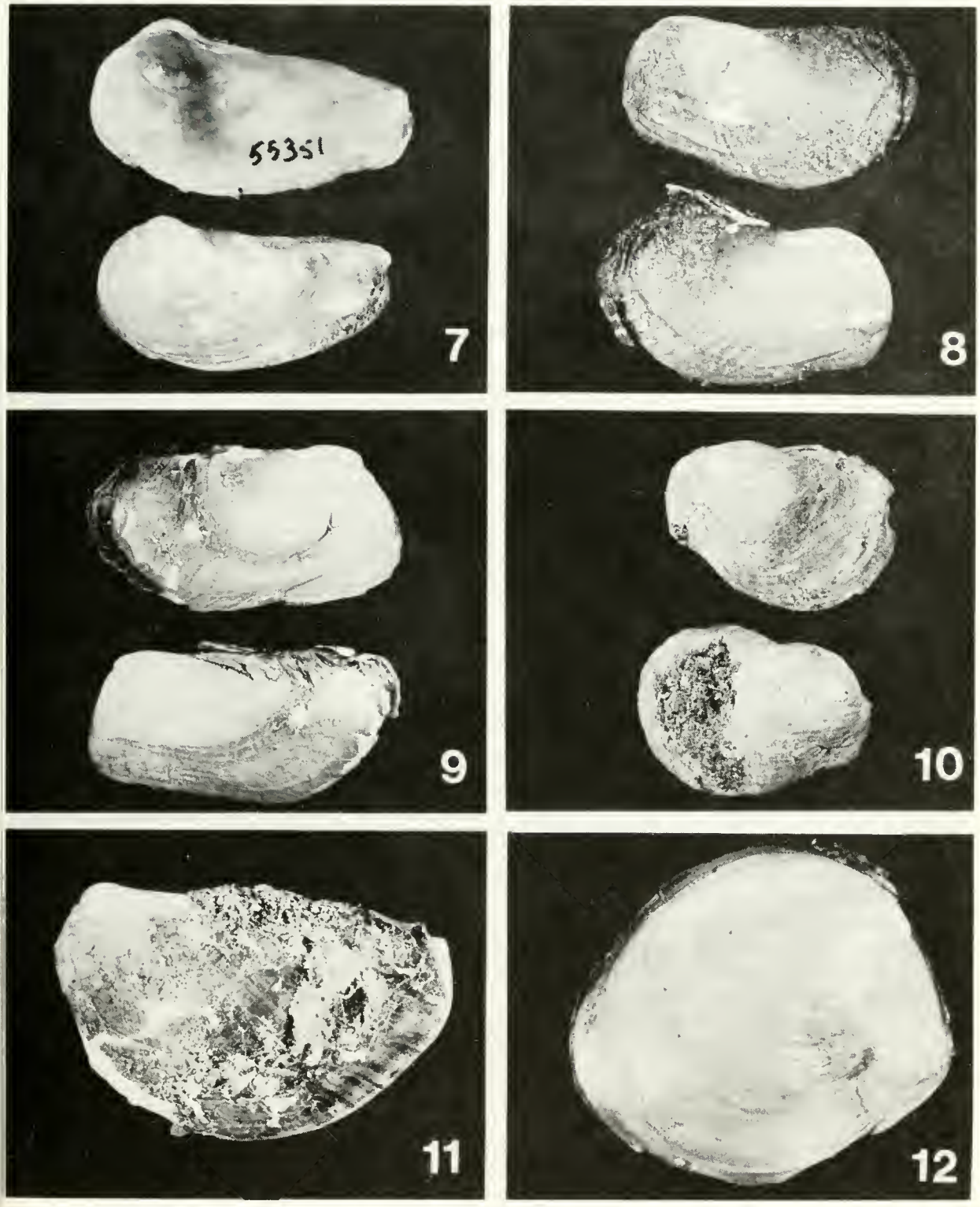
Systematics

Family Lyonsiidae, Fischer, 1887

Shell typically inequivalve with left valve generally larger and extending slightly beyond right; shell usually with a weakly developed prismatic layer and a thick biphasic (lenticular plus sheet) nacre; periostracum often well developed and extending beyond shell edge especially in posterior region; internal resilium split by a well developed lithodesma; resilium possesses a dense array of long, aragonitic needles which lie in a plane normal to hinge and lithodesma; mantle edges fused (Type C fusion (Yonge, 1957)) by the inner and middle folds leaving only four openings into the mantle cavity (inhalent and exhalent siphons, pedal aperture, fourth pallial atrium); mantle edge may possess discrete multicellular, club-shaped mantle glands which secrete a mucoid substance in conjunction with periostracum and function in adhesion of foreign particles to shell exterior; siphons short, split, with short fringes or ten-



FIGS. 1–6. 1, Lyonsia pugetensis, *Sitka Harbor, Alaska; length = 28 mm.* 2, Lyonsia californica, *Venice, California; length = 19 mm.* 3, Lyonsia hyalina, *Marthas Vineyard, Massachusetts; length = 17 mm.* 4, Lyonsia floridana, *Sanibel Island, Florida; length = 10 mm.* 5, Entodesma saxicola, *Friday Harbor, Washington; length = 39 mm.* 6, Entodesma truncatissima, *Hokkaido, Japan; length = 67 mm.*



FIGS. 7–12. **7,** Entodesma cuneata, *Iquiqui, Peru; length = 36 mm.* **8,** Entodesma patagonica, *Punta Balneario, Argentina; length = 17 mm.* **9,** Entodesma fretalis, *Corral Bay, Chile; length = 31 mm.* **10,** Entodesma chilensis, *Corral Bay, Chile; length = 22 mm.* **11,** Entodesma beana, *Myrtle Beach, South Carolina; length = 28 mm.* **12,** Mytilimeria nuttalli, *Venice, California; length = 24 mm.*

tacles; anterior few filaments of inner demibranch of gill fused with inner portion of palp (Category II, Stasek, 1963); outer demibranch of gill composed of a single, upturned lamella (Type E, Atkins, 1937); Type IV stomach (Purchon, 1958, 1960); simultaneous hermaphrodites with large ova possessing numerous, thick gelatinous coats.

Genus *Lyonsia* Turton, 1822

Figs. 1–4

Type *Mya striata* Montagu, 1815 (=*M. norwegica* Gmelin, 1791).

1788 *Mya* Chemnitz, Conch. Cab. **10**:345, pl. 170, figs. 1647–1648. (non-binomial).
1802 *Pandora* Bosc, Hist. Nat. Coq. **2**:243. Non Bruguière, 1797.
1802 *Pandore* Bosc, Hist. Nat. Coq. **2**:243, pl. 14, fig. 1. (error for *Pandora*).
1822 *Lyonsia* Turton, Conch. Insul. Brit. p. 35, pl. 3, figs. 6–7.
1827 *Magdala*, Brown, Illustr. Recent Conch. Great Brit., pl. 11, figs. 1, 2 and 10.
1827 *Hiatella* Brown, Illustr. Recent Conch. Great Brit., pl. 16, figs. 26–27. Non Bosc, 1801.
1830 *Tetragonoste* Deshayes, Encycl. Method., Vers **3**:590. (vernacular name).
1833 *Myatella* Brown, Conch. Text-Book, p. 142, pl. 16, figs. 12 and 30.
1833 *Pandorina* Scacchi, Osserv. Zool., p. 14, Non Borg St. Vincent, 1827 (Protozoa).
1835 *Osteodesma* Deshayes, in Lamarck, Anim. s. vert., 2nd Ed., **6**:85, 129. Non Blainville, 1825.
1926 *Eudorina* Pascher, Arch. Protestenk. **53**:470–471.
1969 *Arenolyonsia* Nordsieck, Die europaeischen Meeresmuscheln eis. Kapverden. Mittlemeer, Schwarzes Meer, p. 156. (Type: *arenosa* Möller, 1842).

Shell elongate, inequilateral, posterior region from umbones usually longer and tapering to a truncated siphonal region; shell with siphonal gape; typically a dense cover of foreign material, usually sand, covering at least a portion of the shell's exterior; shell radially ornamented with numerous, small truncated spines; periostracum thin with fine radial striations and adherent mucoid strands emanating from mantle edge; small but prominent lithodesma; prismatic shell layer thin and lenticular and sheet nacre layers well developed; ratio of distance from umbo to anterior edge and umbo to posterior edge usually around 1:2.5; anterior/posterior shell axis parallel to body axis (measured from dorsal edge of adductor muscles); mantle edge and siphons thin and nonmuscular; band of numerous, small darkly pigmented photoreceptor organs present on exhalent siphon; arenophilic mantle glands numerous, lining most of mantle edge at regular intervals and secreting a mucoid product into the periostracal groove and over the periostracum; periostracal groove well defined; unfused portions of mantle edge reveal typical three-fold edge; pedal aperture long, narrow and lacking internal rim; foot long, laterally flattened, active with well developed byssal gland producing only a few, fine byssal threads; isomyarian to slightly heteromyarian; adductor scars poorly delimited on shells; shallow burrowers in fine sands or muds.

Entodesma Philippi, 1845

Figs. 5–13

Type *Entodesma chilensis* Philippi, 1845.

1818 *Mya* Lamarck, *Anim. s. vert.* **5**:461. (in part).
1830 *Tetragonoste* Deshayes, Encycl. Method., Vers **2**:590. (vernacular name).
1835 *Osteodesma* Deshayes in Lamarck, *Anim. s. vert.*, 2nd Ed. **6**:75, 84.
1845 *Entodesma* Philippi, Arch. Naturgesch. **2**:52, 53.
1849 *Tetragostea* Herrmannsen, Index Genera Moll. **2**:565.
1909 *Agriodesma* Dall, *Proc. U.S. Nat. Mus.* **37**:284.

Thick-shelled bivalves with a thick, often brown or green, periostracum; valves commonly crack when dried; lithodesma large; periostracum often with radial striations; typically rock crevice or algal holdfast dwellers that may conform to shape of nesting site; shell often with byssal notch located posterio-ventrally; anterior:posterior length ratio from umbones greater than 1:2.5; adult shells often with thick, outer granular homogeneous layer, always with a weak prismatic and biphasic nacre; anterior/posterior body axis not parallel to shell longitudinal axis; mantle edge and siphons extremely muscular; arenophilic radial mantle glands usually present in juveniles where they open distal to the periostracal groove; arenophilic mantle glands may gradually be lost with growth; inner mantle epithelium densely packed with mucocytes; periostracal groove and mantle folds poorly defined; siphons often brightly colored and lacking photoreceptors; foot small, cylindrical with well developed byssal gland producing numerous thick, strong threads; pedal

gape small, circular with raised internal rim; muscle scars usually well defined; slightly heteromyarian with anterior adductor smaller than posterior adductor and displaced ventrad; some indication of temporary marsupium in suprabranchial chamber.

Genus *Mytilimeria* Conrad, 1837

Fig. 14

Type *Mytilimeria nuttalli* Conrad, 1837.

1837 *Mytilimeria* Conrad, Journ. Acad. Nat. Sci. 7:246–247, pl. 19, fig. 5.

Thin-shelled bivalves with rounded shells; umbones may be slightly recurved; periostracum thin and often light golden-brown color; no radial ornamentation but periostracum covered with numerous small, crater like pores; usually embedded within compound tunicates; periostracum firmly attached to ascidian host and often peels away when the clam is removed from the tunicate; lithodesma short, squat; anterior:posterior umbonal length ratio usually less than 1:2.5; adult shells with thin homogeneous layer, well-developed prismatic layer and a biphasic nacre; anterior/posterior body axis oblique to shell longitudinal axis; mantle edge broad and flat with well developed orbital musculature; mantle edge contains a deep purple pigment; lacks mantle glands; siphons muscular with wide atrial diameters and no photoreceptors; siphons with numerous apically situated and brightly pigmented short fringes, often appearing to match coloration of host tunicate; inner mantle epithelium with a dense array of mucocytes; foot very small, cylindrical with poorly developed byssal glands able to produce only a few thin byssal threads; pedal aperture very small, circular; heteromyarian with anterior adductor small and displaced ventrad.

Entodesma beana (Orbigny, 1842) new combination

Figs. 11, 13

1845 *Lyonsia beana* Orbigny, Sagra, Hist. Cuba, Moll. 2: 225, pl. 25, figs. 26–28.

1850 *Lyonsia braziliensis* Gould, Proc. Boston Soc. Nat. Hist. 3:219.

1857 *Osteodesma orbigny* Fischer, Journ. Conchyl. 11:383, pl. 11, figs. 7–8.

1928 *Lyonsia beana* Lamy, Journ. Conchyl. 72:258.

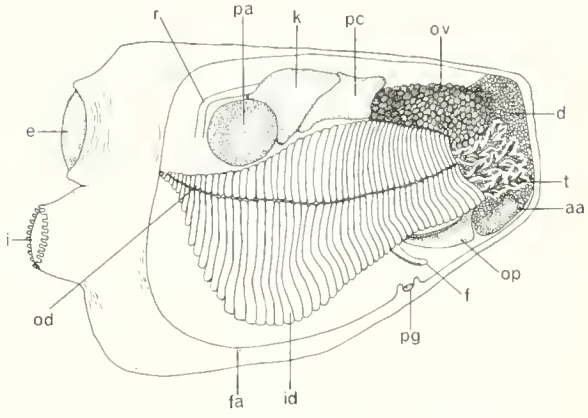


FIG. 13. Entodesma beana *soft part morphology.*

While still listing it as *Lyonsia beana* (subgenus *Philippia*), Abbott (1974) suspected that this "may be an *Entodesma*." Moore (1969) noted that the type for *Philippina* (placed within *Entodesma*) is *Lyonsia beana*. Many characteristics of this species immediately remove it from *Lyonsia* and place it in the redefined genus *Entodesma*. The overall shell shape is entodesmid; that is, it is anteriorly gently tapered to a rounded edge with the umbo located very close to the anterior of the shell. The posterior end of the shell is broad and truncate and the anterior/posterior length ratio form the umbo is close to 1:6. The periostracum is thick, brown and wrinkled in places (especially posteriorly), and there is rarely a partial sand cover on the shell. The ventral edge of the shell has a shallow byssal notch. Juvenile shell consists of a thin prismatic layer and a thick sheet nacre (Prezant, 1980b). The apparent lack of a lenticular nacre in juveniles is a rare modification of lyonsiid shells. Larger specimens of *E. beana* possess a typical biphasic nacre (i.e., composed of lenticular plus sheet nacre). There are several weak radial striations aligning the shell. Muscle scars are well defined on the internal shell. The lithodesma is long and narrow.

The mantle edge of *E. beana* is muscular with dense bundles of oribtal muscles. The fourth pallial artrium is extremely small and difficult to discern but is located directly beneath the posterior adductor muscle. Arenophilic mantle glands line a part of the mantle edge in juve-

niles, usually along the posterior pedal gape and the siphons, and open distal to the periostracal groove. Specimens examined (NMNH) from Cape Hatteras, North Carolina, southward to the coast of Brazil, were found in algal or seagrass beds, in gravel or associated with sponges or coelenterates. Many of these specimens had a partial sand cover near the byssal notch or near the posterior shell region. This sediment coat correlates well with the location of the mantle glands.

The small, wormlike foot expands dorsally into a distended region with a very large, circular byssal orifice. The byssal groove runs almost the entire length of the posterior side of the foot. A small, circular pedal aperture is present and has a distinct, raised internal rim.

E. beana is heteromyarian with a small anterior adductor muscle located ventrally, below the anterior part of the ctenidia. The anterior adductor muscle is narrow and situated in an oblique position along the ventral curvature of the anterior shell edge. The posterior adductor muscle is about twice as large as the anterior adductor and is oval in sagittal section. The former is situated well away from the shell edge while the anterior adductor is located very close to the shell edge.

The muscular siphons lack photoreceptors but are well endowed with numerous, small tentacles.

In one specimen the narrow suprabranchial chamber was densely packed with numerous, large eggs. During the study this has also been observed in *E. chilensis* and *E. saxicola*. This finding may be indicative of a temporary marsupium in some species of *Entodesma*.

Entodesma fretalis (Dall, 1915) new combination

Figs. 9, 14

1915 *Lyonsia fretalis* Dall, Proc. U.S. Nat. Mus. **49**:454.

The type locality for this species is the Straits of Magellan at a depth of about 38 meters (Dall, 1915). The type description of the species corresponds with the generic redefinition offered here and, indeed, *Entodesma fretalis* and *E. chilensis* are quite similar. In all specimens recently examined, shells are distinctly entodesmid. The valves are only slightly tapered anteriorly but are broad and truncated posteriorly. The average umbo length ratio is 1:4.6, the umbo being located very close to the anterior edge.

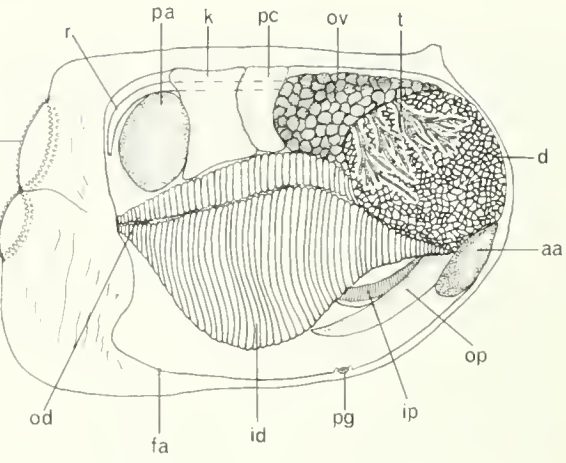


FIG. 14. Entodesma fretalis *soft part morphology.*

The periostracum is ornamented with several raised radial striations and is usually thick and brown, and extends beyond the shell edge (especially posteriorly). The shell proper is composed of thin prismatic, thick lenticular, and thick sheet nacre in juvenile specimens. Large adult shells have not been examined ultrastructurally. The lithodesma is large, usually about 1/5 the shell length.

The mantle edge is highly muscular, especially with radial musculature. The inner mantle epithelium is densely packed with mucocytes. Many arenophilic radial mantle glands are present in juveniles which open distal to the periostracal groove. Secretion from these glads penetrates the periostracum, and there is sporadic, partial sand adhesion on some shells. A small fourth pallial atrium is present directly beneath the posterior adductor muscle.

The foot is very small and appears to be dorsoventrally compressed in preserved specimens. There is a very large byssal orifice and a well defined byssal groove which runs almost to the tip of the foot. The small, circular pedal aperture has a raised internal rim.

Entodesma fretalis is heteromyarian with the posterior adductor being about 1½ times the

size of the anterior adductor. The anterior adductor is also displaced ventrally so that the dorsal edge of the latter is aligned with the ventral edge of the posterior adductor. Thus the body axis is oblique to the shell longitudinal axis. The anterior adductor is also compressed in the anterio-posterior plane.

The siphons of this species are very muscular and are apically covered with a dense array of short, frilly tentacles. There are no photoreceptors on the siphons.

Dissection of several specimens revealed densely packed ova within the suprabranchial chamber similar to conditions found in *Entodesma beana* and *E. saxicola*. The eggs seem to align neatly along the branchial filaments.

Entodesma cuneata (Gray, 1828)

Fig. 7

1828 *Anatina cuneata* Gray, Spicilegia Zoologica 1:6, pl. 3, fig. 12.
1843 *Osteodesma cuneata* Hanley, Cat. Recent Bivalve Shells: 25.
1843 *Osteodesma cuneata* Deshayes, Treat. elém. Conch. 1:215, pl. 9, figs. 7–8.
1846 *Lyonsia cuneata* Orbigny, Voy. Amér. merid 5(Moll.): 518.
1856 *Mytilimeria cuneata* H. and A. Adams, Gen. Recent Moll. 2:364.
1907 *Lyonsia cuneata* Melvill and Standen, Mar. Moll. Scottish Nation. Antarct. Exped., Trans. R. Soc. Edinburgh 46:151.
1909 *Entodesma cuneata* Dall, Shells Peru, Proc. U.S. Nat. Mus. 37:259.
1914 *Lyonsia cuneata* Melvill and Standen, Ann. Mag. Nat. Hist. 13(8):136.
1928 *Lyonsia (Entodesma) cuneata* Lamy, Journ. Conchyl. 72:256.
1951 *Entodesma cuneata* Carcelles and Williamson, Rev. Inst. Nac. Inv. Cienc. Nat. 2:348.
1972 *Entodesma cuneata* Dell, Recs. Dominion Mus. 8(3): 29, fig. 23.

Dall, (1909), on the basis of shell characteristics, was the first to place *Lyonsia cuneata* in *Entodesma*. Soft parts have not been examined, but shell ultrastructure (Prezant, 1981) appears to substantiate this generic change. Large specimens of *E. cuneata* have a thick brown periostracum which is often frayed and wrinkled (especially posteriorly). The shells have a thick, well developed granular homogeneous layer located above a poorly developed prismatic layer and a biphasic nacre. There is a large, recurved lithodesma.

Dall (1910) synonymized *Entodesma cuneata* and *E. chilensis* on the basis of reports of other authors but retracted this synonymy in his review of some Anomalodesmata (1915) where he states that *E. chilensis* and *E. cuneata* are "very different" shells. As Dell (1972) points out, entodesmids are typically found nestled within rocky crevices and their growth form conforms to their surroundings. Thus species of *Entodesma* can vary in shape according to their habitat. However, distinct differences in length to umbo ratios, and the broad, round posterior margin in *E. chilensis* as compared to the long, tapering, truncated siphonal margin in *E. cuneata*, indicates these are separate species. A detailed examination of soft parts of *E. cuneata* is still a necessity.

Entodesma patagonica (Orbigny, 1846)

Fig. 8

1846 *Lyonsia patagonica* Orbigny, Voy. dans l'Amér. Merid. 5:517, pl. 81, figs. 13–14.
1915 *Lyonsia patagonica* Dall, Proc. U.S. Nat. Mus. 49: 454.
1928 *Lyonsia patagonica* Lamy, Journ. Conchyl. 72:258.
1944 *Lyonsia patagonica* Carcelles, Rev. Mus. La Plata 3:292, pl. 14, fig. 113.
1967 *Lyonsia patagonica* Castellanos, An. Com. Inv. Cient. Buenos Aires 8:280, pl. 24, figs. 11–12.
1972 *Entodesma patagonica* Dell, Recs. Dominion Mus. 8(3):31, fig. 26.

In his 1915 work on the Anomalodesmata of the west coast of America, Dall again wrote that *Lyonsia patagonica* "is probably an *Entodesma*". Dell (1972) examined the type specimens at the British Museum of Natural History and confirmed this diagnosis on the basis of gross shell morphology. Juvenile shells of this species have a thin prismatic layer and a biphasic nacre. There is a long, thin lithodesma. The umbonal length ratio of this species is about 1:3.8 and thus fits the *Entodesma* pattern well. The soft parts of this species also confirm its identity as an *Entodesma*. The mantle edge and siphons are highly muscular. There are no photoreceptors. Mantle glands are numerous in juveniles and open distal to the periostracal groove. A small fourth pallial atrium is present below the

posterior adductor. In this species the fourth atrium has a slightly raised internal rim.

The foot is small and cylindrical, and has a very large byssal orifice. The pedal aperture is small and circular and has a well defined raised internal rim.

The species is slightly heteromyarian with a large, circular, posterior adductor muscle (in sagittal section) and a smaller, ovoid, anterior adductor which is slightly ventrad.

DISCUSSION

The taxonomic development of the family Lyonsiidae reflects the gradual accumulation of data on these bivalves and the incorporation of these data into the groups' systematics. Dall (1903) originally placed only the genus *Lyonsia* in the lyonsiids with two subgenera: *Lyonsia* s.s. and *Entodesma*, with the latter divided into two sections, *Allograma* (Dall, 1903) and *Philippina* (Dall, 1900). In 1915, Dall gave *Allograma* subgeneric status and added *Agriodesma* as a section of the subgenus *Entodesma*. Conrad (1837) thought *Mytilimeria* was allied with the mytilids but Dall (1915) tentatively placed the genus *Mytilimeria* in the Lyonsiidae. Habe (1952) gave generic status to *Allograma* with *Bentholyonsia* as a subgenus. Habe (1977) divided the Japanese Lyonsiidae into four genera: *Lyonsia*, *Allograma*, *Bentholyonsia* and *Agriodesma*. It is apparent that *Allograma*, described by Habe (1977) and Dall (1903) as being very thin shelled and having fine radial striations over the shell, short siphons with numerous fringes or tentacles, anterior-posteriorly elongated shell with a circular anterior end and an elongated posterior end with a siphonal gape, is not separable from *Lyonsia* as here defined. The umbones are also situated close to the midpoint of the longitudinal axis of the shell (umbonal length ratio of about 1:1.2). *Allograma* certainly does not belong as a subtaxon of the thicker shelled, more heterogeneously shaped and more posteriorly drawn out *Entodesma* and characteristics of *Allograma* are not sufficient to warrant generic status. Taxonomic characteristics of species of *Allograma* overlap extensively with characteristics of *Lyonsia* and these bivalves should therefore be transferred to the latter genus.

A similar situation exists for *Bentholyonsia*, originally described by Habe (1952). Habe (1977) described this genus as very thin shelled, ovoidal ellipsoidally shaped, with a circular anterior end, and a straight wider posterior end with a siphonal gape, having a shell with fine radial ribs, a glossy shell interior, and found living on fine sands. Moore (1969) maintains subgeneric status for *Bentholyonsia* on the basis of radially arranged granules on the shell's exterior, a lack of radial ribs, a posterior shell gape and a large lithodesma. The apparent conflict concerning radial ornamentation may indicate poor definition of terms, condition of material, or a variable character not valid in diagnosis at or above the species level. The overall definition nevertheless fits the genus *Lyonsia* well. The umbo is situated centrally in *Bentholyonsia* and approximates a 1:1 umbonal length ratio. Species of *Bentholyonsia* should be transferred to *Lyonsia*.

Species of *Agriodesma* on the other hand should be allocated to *Entodesma*. This relationship was recognized by Abbott (1974) when he placed *Agriodesma* as a subgenus of *Entodesma*. The umbonal length ratios of Japanes species of *Agriodesma* described by Habe (1977) range from 1:3.8 to 1:5.6, obviously within the *Entodesma* range. Habe (1977) defined individuals in this "genus" as medium to large in size, having an anteriorly situated umbo, radial ribbing of the shell, thick brown periostracum in larger specimens, commonly ovoidal ellipsoid, posterior end of shell wide and straight, having a glossy interior, and often living among the roots of seaweeds. This same author tentatively synonymized *E. truncatissima* with *A. naviculum* (A. Adams and Reeve, 1850).

The use of subgenera or sections for lyonsiids by many early authors (Lamy, 1928; Dall, 1909, Thiele, 1935) and continued by Keen (1971) and Abbott (1974) in their comprehensive volumes on American molluscs, breaks the family down into several minor components which only serve to confuse the taxonomy. These subdivisions are based upon variable characteristics, such as periostracal color and surface topography (i.e., the subgenus *Agriodesma* Dall, 1909 of the

genus *Entodesma*, is distinguished from *Entodesma* s.s. by its coarse periostracum, and the subgenus *Phlycticoncha* Bartsch and Rehder, 1940 (=*Phlyctiderma*, 1939) may have a zigzag coloration of the thin periostracum). The variability in color morphs and periostracal ornamentation or thickness, which are often worn smooth due to abrasion or growth habits, render these distinctions unreliable. Within the Lyonsiidae, divisions between the three marine genera are clear, and the variability within a given species sufficient to warrant the disuse of subgeneric taxa and use only of generic and specific ranks.

Definitions offered in this paper should be applicable to all marine lyonsiids. It is important to note that there is a strong association between internal anatomy, ecology, and shell structure; for example, the overall modification of shell gape corresponds well with the degree of heteromyarianism and changes of habitat. As in mussels, increased dependence upon a byssal system results, in evolutionary terms, in expanded importance of the posterior region of the bivalve, i.e., the siphonal area and associated shell and structures. Increased stabilization and decreased exposure resulting from firm byssal attachment within crevices resulted in a more pronounced elaboration of the posterior region of species of *Entodesma* than in *Lyonsia*. Yonge (1952) cites these differences as extending internally to include the adductor muscles, and leading, in part, to the more pronounced heteromyarian condition found in *Entodesma*. The elaboration of the siphonal area has resulted in a hypertrophy of the active posterior region. Partially because of the endosymbiont habit that results in external well distributed support, *Mytilimeria nuttalli* has assumed a circular or globular shape.

Taxonomic definitions of the marine genera offered here reveal a plasticity of the Lyonsiidae that partially accounts for their phylogenetic and ecologic divergence. The slender shell and relatively active pedal system of *Lyonsia* are well adapted for burrowing. The weak byssal system is supplemented by the extraneous sand coat on their shells, and this adhesion is supported by the mucoprotein produced by the arenophilic mantle glands (Prezant, 1979a). The mucoid secretion adheres firmly to the periostracum and is entangled among the numerous shell spinules (Prezant, 1979b). The high nacre content of the shell allows the valves to remain thin yet strong and fracture resistant. Light-shadow reactive siphonal photoreceptors serve the bivalve in detecting large predators in shallow waters, and also in the detection of light-dark cycles. The adaptive significance of the shell ultrastructure is discussed elsewhere as is the role and phylogenetic implications of the arenophilic radial mantle glands (Prezant, 1980; 1981).

Many species of *Entodesma* have assumed a life-style nestled within crevices along a rocky intertidal shoreline. These bivalves are often exposed to harsh physical stresses from tidal impacts and have developed a thick periostracum and shell and an energetically inexpensive, fracture resistant, homogeneous layer (Prezant, 1981). Thick byssal threads help secure the animal in place. A reduction in the number of arenophilic radial mantle glands occurs with growth and increased shell thickness. The nestling habit probably affords protection from some potential predators. *Entodesma* lacks photoreceptors but the nestling habits may leave the bivalve in poorly lit areas anyway.

Mytilimeria lacks photoreceptors, an active byssus, arenophilic radial mantle glands, and possesses a very thin shell. These characteristics fit the bivalves well in their endosymbiont habit. The enveloping ascidian has coincidentally assumed the role of stablizing, protecting and camouflaging the bivalve. In turn *Mytilimeria* has developed wide siphonal atria, cryptic coloration of siphons to match their host test, and a physically adhesive periostracum which binds the bivalve tightly to the tunicate.

Yonge (1952) believed that the byssus of adult *Mytilimeria nuttalli* had regressed to the point of nonfunction, although he did note byssi in juveniles. This was a reasonable assumption for adult clams since it is difficult to find even remnants of byssi within the tunicate. Furthermore there appears to be little need of a byssus for a bivalve dwelling within a sessile ascidian. Adult *M. nuttalli*, however, when placed outside their

hosts will produce a few thin byssal threads reminiscent of those in *Lyonsia*. Both of these genera have developed other extraneous modes of stabilization. *Entodesma*, on the other hand, exposed to the rigors of intertidal, often rocky shorelines, has evolved a system of numerous, strong byssal threads and a thick shell and periostracum.

Coe (1943) in a discussion of functional hermaphroditism among bivalves noted that most hermaphrodites are also brooders. In three species of *Entodesma (saxicola, chilensis* and *fretalis)* numerous ova have repeatedly been found within the suprabranchial chamber of the gills. It is uncertain if this represents true brooding, or is the result of some environmental or preservation artifact that caused expulsion of ova into this cavity. Eggs are exceptionally large in some Anomalodesmata (Morgan and Allen, 1976), and larvae may have a short larval existence. Brooding seems reasonable since many species of *Entodesma* live in a rigorous environment in which larvae, even if present in the plankton for a short time, may quickly be washed into a zone without appropriate substrata for settlement. If released in a late stage of development, larvae may be able to settle quickly out of the water column within a single tidal cycle and remain within a suitable environment. Eggs examined in these three species, however, did not show any signs of development, and, indeed, may not have been fertilized. It may be possible that the suprabranchial chamber acts as a holding chamber prior to internal fertilization. In this way gametes may not be washed away prior to fertilization. The reproductive and life cycles of species of *Entodesma* have yet to be examined.

Morrison (1943) described *Guianadesma sinuosum* and placed this freshwater bivalve in the Lyonsiidae. Morrison (1943) reported *G. sinuosum* as having a small, cylindrical foot, with a large byssus gland and a large byssal orifice; being slightly heteromyarian with a larger posterior adductor; having fused mantle lobes except for the siphonal and pedal apertures; with papillose siphons; well developed brown periostracum; small, rhomboidal, inequivalve shell; being edentulous; having rounded anterior end and truncate posterior end; raised radial striations; umbones about one-third from anterior end; and internal ligament lacking a lithodesma. These molluscs were found attached by byssal threads to rocks in midstream of the Cuyuni River, Guyana. Specimens personally examined (ANSP) appeared *"Entodesma"* like, as did the shell description offered by Morrison (1943). Muscle scars were well imprinted on the shell interior, and the umbonal length ratio was about 1:3.5. The periostracum appeared clean (i.e., no adhering sediments) in specimens examined including the type specimens (NMNH -J. P. E. Morrison, personal communication). The gonadal and gill structures, presence of arenophilic mantle glands, and shell ultrastructure are presently unknown and these must be examined prior to final taxonomic categorization.

The evolutionary modifications and adaptations within the Lyonsiidae have resulted in three distinct marine genera, readily separable and easily characterized, and well suited to the diverse habitats in which they occur. Because of the distinct tripartite divergence revealed in this taxonomic analysis, subgeneric taxa for the marine Lyonsiidae should be abandoned.

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Abbreviations Used in Drawings

aa – anterior adductor muscle
d – digestive diverticula
e – exhalent siphon
f – foot
fa – fourth pallial aperture
i – inhalent siphon
id – inner demibranch
ip – inner labial palp
k – kidney
od – outer demibranch
op – outer labial palp
ov – ovary
pa – posterior adductor muscle
pc – pericardial chamber
pg – pedal gape
r – rectum
t – testis

A NEW GENUS OF TURBINELLIDAE (GASTROPODA: PROSOBRANCHIA), WITH THE DESCRIPTION OF A NEW SPECIES FROM THE CARIBBEAN SEA

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ABSTRACT

Cyomesus, *a new genus, is proposed to receive four species of Turbinellidae previously assigned to* Mesorhytis *Meek, 1876,* Teramachia *Kuroda, 1931, and* Benthovoluta *Kuroda and Habe, 1950. All four species are reviewed, and a new species,* Cyomesus aratiunculus, *is described from near the Virgin Islands.*

Investigations of the tropical Atlantic and eastern Pacific deep-sea by the University of Miami have resulted in one of the most extensive collections of tropical deep-sea mollusks in the world. Most of this remarkable assemblage remains to be examined. These collections contain specimens of three of the four western Atlantic species of *Cyomesus*, a previously undescribed genus. Since the species here assigned to *Cyomesus* have been the subject of much nomenclatural confusion, a review of all species is presented. The taxonomic history of the genus is reviewed and the relationships of *Cyomesus* to other genera within the Turbinellidae are briefly discussed.

Specimens on which this paper was based are housed in the Invertebrate Research Collection of the Rosenstiel School of Marine and Atmospheric Science, University of Miami (RSMAS), designated by the abbreviation UMML, the National Museum of Natural History, Smithsonian Institution (USNM), and the Museum of Comparative Zoology, Harvard University (MCZ).

Family Turbinellidae Swainson, 1840
Subfamily Ptychatractinae Stimpson, 1865
Cyomesus gen. nov.

Mesorhytis: Dall, 1889a: 172; 1889b: 112; 1890: 317. – Johnson, 1934: 127. – Cernohorsky, 1970: 51; 1972: 218. (*Non Mesorhytis* Meek, 1876: 356, 364).
Prodallia Bartsch, 1942: 12 (*partim*).
Teramachia: Weaver and duPont, 1970: 176 (*partim*). – Bayer, 1971: 195. – Abbott, 1974: 243. (*Non Teramachia* Kuroda, 1931: 45).

Benthovoluta: Rehder, 1972: 7, 8 (*partim*).–Cernohorsky, 1973: 126 (*partim*).

Type-species–*Fasciolaria (Mesorhytis) Meekiana* Dall, 1889; herein designated.

Gender–Masculine.

Description–Shell fusiform, elongate, of moderate size; spire extended, 40–50% of total shell height. Whorls broadly rounded peripherally, constricted anteriorly; siphonal canal relatively short, broad, slightly reflexed. Sculpture on early whorls of strong axial ribs, usually becoming obsolete on later whorls; spiral sculpture present or absent. Aperture lanceolate, outer lip slightly flared anteriorly in adult. Columella slightly flexed, with 3 high, thin, oblique plaits, posteriormost strongest; parietal wall with very thin glaze. Operculum small, thin, spatulate, slightly curved, with terminal nucleus. Radula triserial; rhachidian multicuspid, with saddle-shaped base; laterals with elongate base and distal, clawlike cusp.

Remarks–The species here assigned to *Cyomesus* have been placed previously in *Mesorhytis* Meek, 1876, *Teramachia* Kuroda, 1931, and/or *Benthovoluta* Kuroda and Habe, 1950. *Teramachia* has usually been accepted as a member of the Volutidae. The uniserial radula of the type-species, *T. tibiaeformis* Kuroda, 1931 (illustrated in Habe, 1952), indicates close relationship with *Calliotectum* Dall, 1890, a volutid (Rehder, 1972; Cernohorsky, 1973). Since Bayer (1971) showed that *Mesorhytis meekiana* Dall, 1889, and *Teramachia chaunax* Bayer, 1971, are turbinellids, *Teramachia* is eliminated as an appropriate genus for the present group.

Mesorhytis was erected by Meek (1876) for a fusiform gastropod fossil from the Cretaceous of Missouri. An examination of the type series of *M. gracilenta* Meek, 1876, showed that *Cyomesus* differed in having less prominent axial sculpture, the whorl periphery more anterior, the columella distinctly twisted to the left anteriorly (not straight), and the columellar plaits more lamelliform, with the posterior (not middle) plait most prominent. However, in view of the general similarity of *Mesorhytis* and *Cyomesus*, it is quite possible that *Mesorhytis* is turbinellid rather than fasciolariid as it has been regarded by most authors (Meek, 1876; Dall, 1889a, 1889b, 1890; Thiele, 1929; Cernohorsky, 1970, 1972) and may be a precursor of *Benthovoluta* or *Surculina* Dall, 1908.

Benthovoluta was introduced by Kuroda and Habe (1950) for *Phenacoptygma? kiiensis* Kuroda, 1931. Kuroda (1965) and Rehder (1967) showed that *Benthovoluta* was turbinellid in affinity rather than volutid. Rehder (1967) also commented on the relationships of *Metzgeria* Norman, 1879, *Ptychatractus* Stimpson, 1865, and *Surculina* Dall, 1908, grouping them together with *Benthovoluta*. In a subsequent paper, Rehder (1972) discussed *"Teramachia" barthelowi* (Bartsch, 1942) and concluded that it should be assigned to *Benthovoluta*. He went on to mention Bayer's (1971) discussion of the Caribbean species *Mesorhytis meekiana*, *M. costatus* Dall, 1890, and *Teramachia chaunax*, and intimated that these species constituted a distinct group of their own, but stopped short of separating them from *Mesorhytis*. Cernohorsky (1973), apparently unaware of Rehder's (1972) paper, independently placed *Teramachia barthelowi* in *Benthovoluta*, but, unlike Rehder, also included *T. chaunax*, *Mesorhytis meekiana*, and *M. costatus*. The relatively large shell with rounded whorls, very long, straight siphonal canal, and low, rounded columellar plaits of *Benthovoluta* distinguish it from *Cyomesus*, and, in my opinion, exclude *"Teramachia" barthelowi* from *Benthovoluta*.

I thus include the following genera in the Ptychatractinae in accordance with Rehder (1967) and Cernohorsky (1973) and with the changes involving *Mesorhytis* and *Cyomesus* discussed above: *Ptychatractus* Stimpson, 1865; *Metzgeria* Norman, 1879; *Mesorhytis* Meek, 1876; *Benthovoluta* Kuroda and Habe, 1950; *Surculina* Dall, 1908; *Cyomesus* gen. nov.; and *Ceratoxancus* Kuroda, 1952 (*fide* Cernohorsky, 1973). Although problematical, the following fossil genera might also be considered turbinellid: *Palcofusimitra* Sohl, 1963, *Mitridomus* Sohl, 1963, and *Fusimitra* Conrad, 1855.

Cyomesus meekianus (Dall, 1889)

Fig. 1

Fasciolaria (Mesorhytis) Meekiana Dall, 1889a: 172, pl. 36, fig. 7; 1889b: 112, pl. 36, fig. 7.

Fasciolaria (Mesorhytis) meekiana: Johnson, 1934: 127.–Rehder, 1972: 8.

Mesorhytis meekiana: Cernohorsky, 1970: 52; 1972: 218.
Teramachia meekiana: Bayer, 1971: 197, figs. 54 (left), 55 D-E.
Benthovoluta meekiana: Cernohorsky, 1973: 127, fig. 2.

Description–See Bayer, 1971.

Lectotype–USNM 86970; herein designated. Length 15.4 mm; width 5.2 mm.

Type-locality–BLAKE sta. 100, off Morro Light, Havana, Cuba, 732 m; herein restricted.

Material examined–BLAKE sta. 100, off Morro Light, Havana, Cuba, 732 m; 1 spec., USNM 86970 (lectotype); 1 spec., USNM 784568 (paralectotype).–BLAKE sta. 16, 23°11′N, 82°23′W, 534 m; 1 spec., MCZ 7243 (paralectotype).–BLAKE sta. 20, 23°02.5′N, 83°11′W, 402 m; 1 spec., MCZ 7242 (paralectotype).–PILLSBURY sta. P-1225, 17°42.5′N, 77°58′W, 457–558 m; 1 spec., UMML 30-8260.

Remarks–*Cyomesus meekianus* remains a very rare species, known only from the specimens cited above. The range of this species includes the three BLAKE stations along the northwest coast of Cuba and the single PILLSBURY station southwest of Jamaica. The PILLSBURY specimen is the largest known for this species, measuring 26.0 mm in length.

Cyomesus chaunax (Bayer, 1971)

Fig. 3

Teramachia chaunax Bayer, 1971: 198, figs. 54 (right), 55 B-C.–Rehder, 1972: 8.–Abbott, 1974: 243.
Benthovoluta chaunax: Cernohorsky, 1973: 127.

Description–See Bayer, 1971.

Holotype–USNM 701216. Length 28.1 mm; width 8.9 mm.

Type-locality–R/V JOHN ELLIOTT PILLSBURY sta. P-904, 13°45.5′N, 61°05.7′W, 201–589 m.

Material examined–PILLSBURY sta. P-904, 13°45.5′N, 61°05.7′W, 201–589 m; 1 spec., USNM 701216 (holotype).–COLUMBUS ISELIN stations in Tongue of the Ocean, Bahamas: CI-80, 23°54′N, 77°04′W, 1244 m; 1 spec., UMML 30-8261.–CI-79, 23°51′N, 76°51′W, 1289 m; 2 spec., UMML 30-8262.–CI-151, 23°52.2′N, 76°48.5′W, 1315 m; 1 spec., UMML 30-8263.–CI-363, 23°51.6′N, 76°51.9′W, 1324–1315 m; 1 spec., UMML 30-8264.–CI-156, 23°44.4′N, 76°48.3′W, 1334 m; 1 spec., UMML 30-8265.–CI-368, 23°43.2′N, 76°50.5′W, 1352–1342 m; 1 spec., UMML 30-8266.–CI-252, 23°38.5′N, 76°47.8′W, 1322–1332 m; 1 spec., UMML 30-8267.–CI-158, 23°30.7′N, 76°56.8′W, 1317 m; 1 spec., UMML 30-8268.–CI-14, 23°33′N, 77°09′W, 1246 m; 1 spec., UMML 30-8269.–CI-163, 23°31.6′N, 77°08.3′W, 1342 m; 1 spec., UMML 30-8270.–CI-47, 23°42′N, 77°08′W, 1372 m; 1 spec., UMML 30-8271.–CI-54, 23°54′N, 77°13′W, 1298 m; 2 spec., UMML 30-8272.–CI-55, 23°57′N, 77°18′W, 1353 m; 1 spec., UMML 30-8273.–CI-303, 23°54.8′N, 77°18.4′W, 1390–1389 m; 2 spec., UMML 30-8274.–CI-365, 23°51.2′N, 77°16′W, 1372 m; 1 spec., UMML 30-8275.–CI-165, 24°04.7′N, 77°22.3′W, 1426 m; 1 spec., UMML 30-8285.–CI-406, 23°57.3′N, 77°20.8′W, 1408–1399 m; 1 spec., UMML 30-8286.

Remarks–This, the most recently described species of *Cyomesus*, is now the best known. The present material considerably extends the range of the species to the north and west. However, it is recorded from two areas, the Tongue of the Ocean, Bahamas, and St. Lucia, with no material from in between, although U.S. Government and University of Miami ships have made numerous collections within that area. Specimens of *C. chaunax* have not been discovered from any of the other Bahamian deep-water basins, although not all of the material collected from Exuma Sound has been sorted. The TOTO specimens of *C. chaunax* show that the species is rather conservative morphologically. Most of these specimens are somewhat more inflated than the type but not exceedingly so. One specimen is 55 mm long, making *C. chaunax* the largest species of the genus.

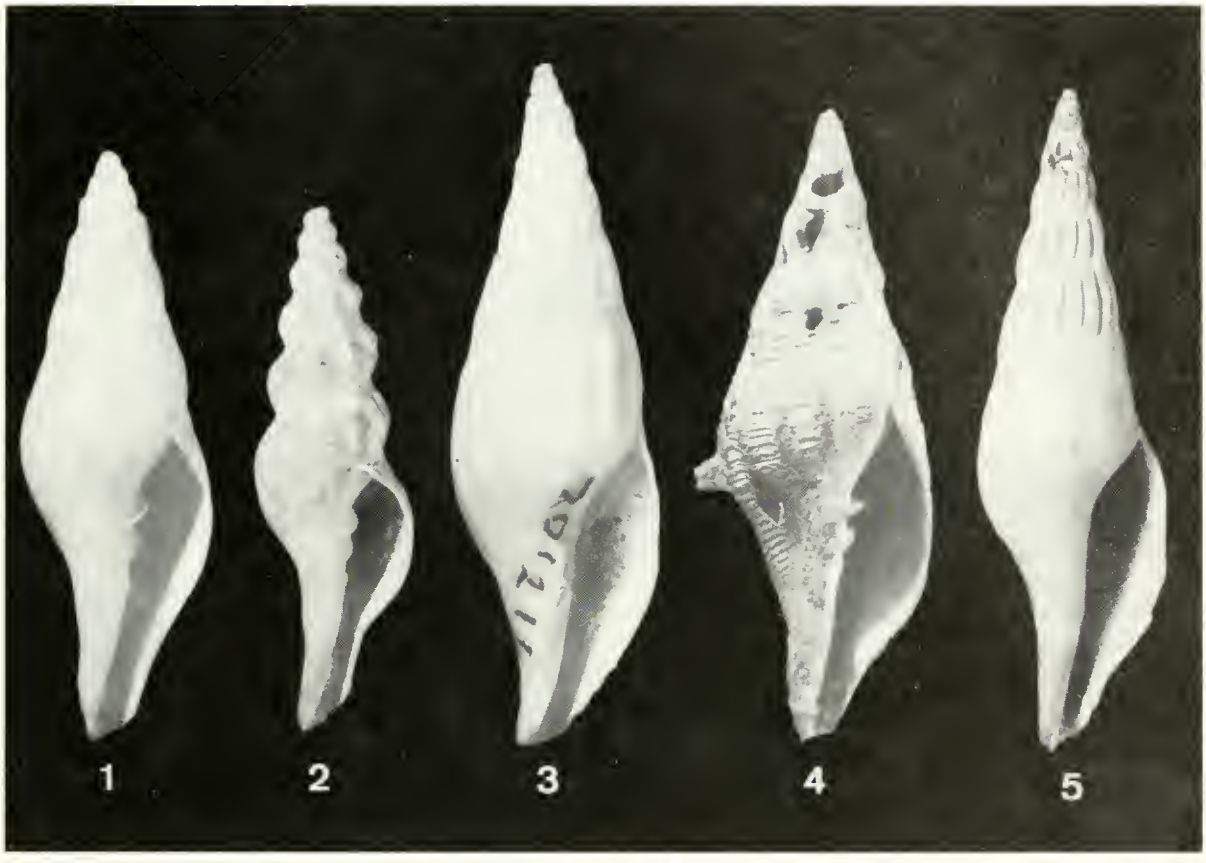
Cyomesus costatus (Dall, 1890)

Fig. 2

Fasciolaria (Mesorhytis) costatus Dall, 1890: 317, pl. 5, fig. 5.
Mesorhytis costatus: Cernohorsky, 1970: 52.–Rehder, 1972: 8.
Teramachia costatus: Bayer, 1971: 197.–Abbott, 1974: 243.
Benthovoluta costata: Cernohorsky, 1973: 129.

Description–See Dall, 1890.

Holotype–USNM 96507. Length 13.8 mm; width 4.5 mm.



FIGS. 1–5. **1**, Cyomesus meekianus *(Dall, 1889). Lectotype, USNM 86970, 15.4 mm.* **2**, Cyomesus costatus *(Dall, 1890). Holotype, USNM 96507, 13.8 mm.* **3**, Cyomesus chaunax *(Bayer, 1971). Holotype, USNM 701216, 28.1 mm.* **4**, Cyomesus aratiunculus *sp. nov. Holotype, USNM 784594, 29.0 mm.* **5**, Cyomesus barthelowi *(Bartsch, 1942). Holotype, USNM 238444, 27.5 mm.*

Type-locality–ALBATROSS sta. 2751, 16°54′N, 63°12′W, 1256 m.

Material examined–See Holotype (only known specimen).

Remarks–Of the four Caribbean species of *Cyomesus, C. costatus* is the most uncharacteristic. However, its strongly convex whorls are similar to the early whorls of *C. meekianus*, and its other characteristics are so similar to the other *Cyomesus* species that I have little doubt *C. costatus* belongs in this group.

Cyomesus aratiunculus sp. nov.

Fig. 4

Description–Shell elongately fusiform, strong, coarsely sculptured. Apical whorls lost, 6½ whorls remaining. Whorls with low, weak axial folds evident only from above to just below periphery, separated from each other by somewhat wider interspaces. Numerous (41 on last whorl) irregular, crowded, unequal spiral threads covering whorls from suture to tip of anterior canal. Suture indistinct. Aperture narrowly lanceolate; outer lip simple; columella twisted to left anteriorly, with 3 oblique, lamelliform plicae, increasing in size from anterior to posterior; parietal wall without callus. Animal unknown.

Holotype–USNM 784594. Length 29.0 mm; width 9.3 mm.

Type-locality–R/V JOHN ELLIOTT PILLSBURY sta. P-984, 18°26.4′N, 63°12.6′W, 430 m.

Material examined–See Holotype (only known specimen).

Remarks—In general shape and size, *Cyomesus aratiunculus* is extremely similar to *C. chaunax* and *C. meekianus*. The axial folds restricted to the periphery and the persistent spiral sculpture immediately distinguish *C. aratiunculus* from the other species.

Cyomesus barthelowi (Bartsch, 1942)

Fig. 5

Prodallia barthelowi Bartsch, 1942: 12, pl. 2, fig. 2.
Teramachia barthelowi: Weaver and duPont, 1970: 177, pl. 75, figs. C, D.—Bayer, 1971: 196–198.
"Teramachia" barthelowi: Rehder, 1972: 7.
Benthovoluta barthelowi: Rehder, 1972: 8.—Cernohorsky, 1973: 127.

Description—See Bartsch, 1942; Weaver and duPont, 1970.

Holotype—USNM 238444. Length 27.5 mm; width 8.0 mm.

Type-locality—ALBATROSS sta. 5425, off Cagayan Island, Sulu Sea, Philippines, 905 m.

Material examined—See Holotype (only known specimen).

Remarks—I am placing this species in *Cyomesus*. However, the unique axial sculpture of deeply incised grooves, presence of two instead of three columellar plicae, and geographic isolation from the Caribbean species may indicate a need for a separate subgenus to accommodate *C. barthelowi*. Soft parts of *C. barthelowi* must be examined before a satisfactory solution can be reached.

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REMARKS ON *MURICODRUPA* IREDALE, 1918 (MURICIDAE: THAIDINAE), WITH THE DESCRIPTION OF A NEW SPECIES

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ABSTRACT

Muricodrupa jacobsoni, *a new species known only from Melanesian populations (Bismarck Archipelago, Solomon and Fiji Islands), is described and dedicated to the late M. K. Jacobson. Radular and opercular figures are provided for* Muricodrupa fenestrata *(Blainville, 1832), and* M. funiculus *(Wood, 1828). A lectotype of* Murex margariticola *Broderip is selected and illustrated, and considered to be a junior synonym of Cronia fiscella (Gmelin, 1791).*

The classification of the numerous species-group taxa with Morula-like shell characters has long presented problems to students of muricacean gastropods. The thaidid genus *Morula* Schumacher, 1817, remains a genus-group receptacle for numerous, small, non-spinose forms with denticulate apertures without regard for the limitations dictated by the characters of the type species, *Drupa uva* Röding, 1798 (cf. Radwin and D'Attilio, 1972). Recent investigations on the radulae of various moruloid species, including those of Arakawa, 1962, 1965; Cernohorsky, 1969; Emerson, 1968, Emerson and Cernohorsky, 1973; Radwin and D'Attilio, 1971, 1972; Wu, 1965, 1968, and others, have advanced the morphological knowledge of these rachiglossate gastropods. The basic familial and subfamilial classification of the Muricacea, however, remains in a state of flux. Some workers largely ignore the radular characters and rely mostly on shell morphology for defining familial-level groups. Such is the case for the thaidid taxa. Some workers separate the Thaididae from the Muricidae, while others recognize subfamilial rank within the Muricidae for the thaidine taxa (see summary by Cernohorksy, 1969, p. 293).

The new species described below belongs to a small group of Indo-Pacific taxa characterized by shells possessing deeply pitted, squarish interspaces formed by the junction of the axial and spiral ribs. In the absence of knowledge on its radular morphology, the present species is tentatively referred to the genus *Muricodrupa* Iredale, 1918, for which the radular dentition of the type species is described and illustrated.

We name this new species in the cherished memory of a longtime friend and valued col-

league, Morris Karl Jacobson (1906–1980), in recognition of his many and varied contributions to the field of malacology.

Family Muricidae Rafinesque, 1815
Subfamily Thaidinae Suter, 1909
Genus *Muricodrupa* Iredale, 1918

Muricodrupa Iredale, 1918, p. 38; Thiele, 1929, p. 295; Wu, 1968, p. 90, radular drawings of "*Muricodrupa elangata* [sic] (Blainville)" pl. 4, figs. 4, 5.

Type species by original designation: *Purpura fenestrata* Blainville, 1832, p. 221, pl. 10, fig. 11. Synonyms: *Murex cariosus* Wood, 1828, Suppl. p. 15, *Murex* pl. 5, fig. 22 [not Linné, 1767, p. 1220]; *Purpura* "alongée" [vernacular for *elongata*] Blainville, 1832, pl. 10, fig. 9, fig. only [*nomen nudum*]; *Purpura cancellata* Quoy and Gaimard, 1833, vol. 2, p. 563, atlas (2), pl. 37, figs. 15–16 [not Röding, 1798, p. 143]; *Ricinula elongata* Reeve, 1846, *Ricinula* no. 25, pl. 4, fig. 25.

Radular characters of type species: Five cusps on the rachidian tooth, with central cusp narrow and long, lateral cusps about ¾ the length of the central cusp, intermediate cusps small and located near the laterals (figs. 5a, 5c); lateral tooth large and normally hooked (fig. 5b).

Opercular characters of type species: Outline broadly unguiculate, margin thickened on one side, central area depressed, with irregular raised, concentric rings on the interior surface (fig. 7b).

Muricodrupa jacobsoni, n. sp.
Figs. 1–4

Description–Shell moderately large for genus, attaining 35+ mm in height, low spired; nature of protoconch unknown (eroded off specimens); suture weakly defined and interrupted by varical buttresses; whorls 4+, weakly convex, shouldered, spire short, blunt. Aperture narrowly ovate, inner lip mostly adherent, outer lip finely fluted, ornamented with 6 well-defined, evenly spaced denticles, set slightly back from apertural margin, with the lowest denticle above the entrance to canal and the uppermost denticle below the shoulder area; anal trough with a prolonged sinus extending above the shoulder, delineated within on the left side by a minor denticle and on the right side by a swollen and more prominent denticle isolated above the 6 lower denticles; canal, broad, mostly open, tapering and recurved distally, siphonal fasciole coarsely sculptured with previous canal terminations; pseudo-umbilical pit present. Sculpture consisting of 6 varices with visibly defined varical margins, rounded with equal or wider interspaces, varices crossing the angulate shoulder slightly oblique and forming buttresses against the previous whorl; shoulder deeply excavated in the interspaces; varices with low, scabrous lamellae on varical leading surface; number of costae increasing by one or two on the spire; 3 primary spiral cords situated on the body, along with an occasional secondary cord; a major cord in concave area below the body; canal with one major cord, supplemented with minor or secondary cords; spiral sculpture crossed by lamellose growth striae, scabrously ornamented where not abraded.

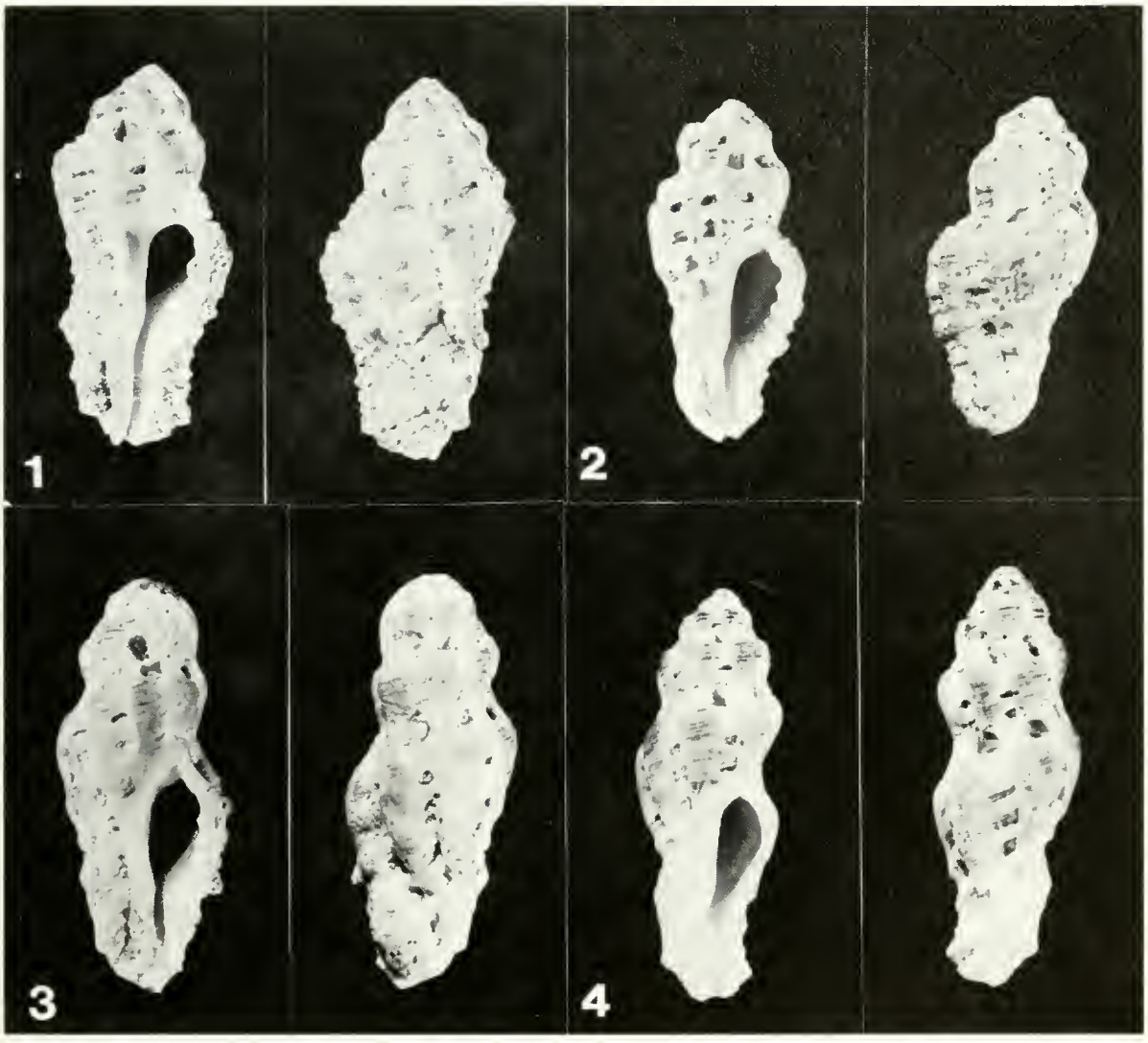
Shell color–matte white, apertural interior white in holotype, tinged with pale violet in paratypes.

Type-locality–Astrolabe Barrier Reef, Yanuyanu-i-lona Island, Fiji Islands (19°55′S, 178°35′E), Kauter and Williamson, 1971.

Holotype from type locality, LACMNH no. 71-205; measurements 35.5 mm in height, 16.9 mm in width; fig. 1. Other material examined: Paratype A, fig. 2, AMNH 201460 (ex-Tulane University, Department of Geology), Manus Island, Bismarck Archipelago; 31.5 mm in height, 16.8 mm in width. Paratype B, fig. 3, SDNHM Type No. 76523, Nudha Island, Solomon Islands, American Mela Expedition Station 18; 38.5 mm in height, 20.2 mm in width. Paratype C, Billee Mabry, June-July, 1978, Billee Mabry Collection, same locality as for Paratype B; 37.2 mm in height, 17.9 mm in width. Paratypes D and E, Guadalcanal, Solomon Islands; paratype D, 36.3 mm in height, 17.1 mm in width; paratype E, fig. 4, 37.8 mm in height, 13.4 mm in width, Thora Whitehead Collection.

DISCUSSION

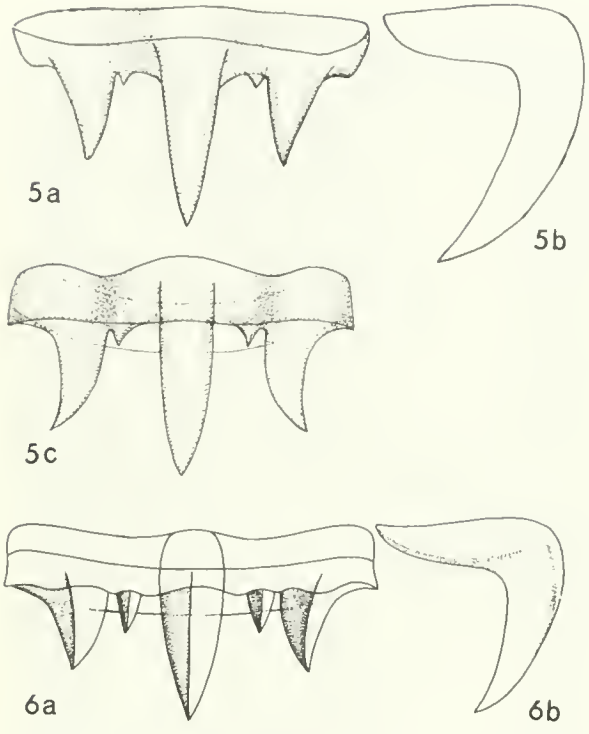
The new species, together with its species-group congeners, is characterized by the prominent cavernous excavations between the varical



FIGS. 1–4. Muricodrupa jacobsoni, *n. sp., all* × 1½. **1**, *holotype, Yanu-yanu-i-loma Island, Fiji Islands, LACMNH 71–205.* **2**, *paratype A, Manus Island, Bismarck Archipelago, AMNH 201460.* **3**, *paratype B, Nudha Island, Solomon Islands, Billee Mabry Collection.* **4**, *paratype E, Rove, Guadalcanal Island, Solomon Islands, Thora Whitehead Collection.*

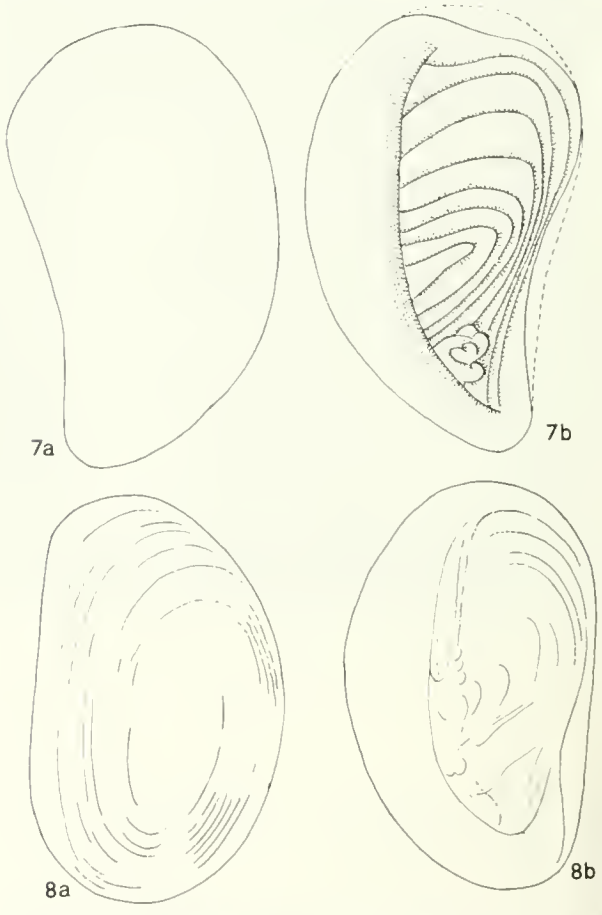
and spiral ridges, which form squarish pits. It is readily distinguished from its closest relatives by the extended narrow form of the shell, the blunt spire and broad canal.

The new species has been confused with *Muricodrupa funiculus* (Wood, 1828, p. 15, *Murex* pl. 5, fig. 17), locality unknown; radula and operculum here illustrated, figs. 6a, b; 8a, b. We consider *Muricodrupa decussata* (Reeve, 1845, *Murex* species 153, pl. 31, fig. 153), "Island of Bohol, Philippines," type specimens not located in the BM(NH) *teste* J. H. McLean and *Muricodrupa triangulata* (Pease, 1868, p. 278, pl. "23a", fig. 15, "Insl. Hawaii") to be junior synonyms of *Muricodrupa funiculus* (Wood, 1828). Compared to the new species, Wood's taxon has an essentially triangular form, is broad at the shoulder relative to height, has a more spinose shoulder carina, and has three denticles anteriorly positioned on the columella.



FIGS. 5a-5c. *Radular dentition of* Muricodrupa fenestrata *(Blainville), greatly enlarged; SW Rarotonga Island, Cook Islands, ANSP 278974.* 6a-6b, *Radular dentition of* Muricodrupa funiculus *(Wood), greatly enlarged; Rodda Reef, Queensland, Australia, SDSNH 51212.*

Kay (1979, p. 238, fig. 83I) assigned *Muricodrupa triangulata* (Pease) to the synonymy of Muricodrupa funiculus (Wood). Cernohorsky (1969, p. 311, pl. 49, fig. 25), however, referred Pease's taxon to the synonymy of *Morula (Cronia) fiscella* (Gmelin, 1791, p. 3552, no. 160), but his figured specimen represents an example of *Muricodrupa funiculus* (Wood). Cernohorsky's nomenclatural interpretation of the identity of *Murex fiscellum* Gmelin was based on the figure citations by Gmelin (1791, p. 3552) to Chemnitz's (1788, vol. 10, pl. 160, figs. 1524, 1525) illustrations and on the descriptive text. Chemnitz's text (*op. cit.*, p. 242) describes the shell as being ". . . strongly clathrate with deeply recessed windows (depressions) which are coloured brown", and Cernohorsky (1969, p. 311) concluded that the ". . . description and figure [*sic*] are only applicable to *M. fiscella* not to *M. margariticola.*" The figures of Chemnitz, however, lack squarish windows, whereas the coloration and sculpture are much closer to *Morula margariticola* (Broderip, 1833, p. 177), as figured by Cernohorsky (1969, p. 312, pl. 49, fig. 26, and 1972, pl. 128, pl. 36, fig. 8). Cernohorsky (1978, p. 69, pl. 20, fig. 5) illustrates what appears to be a specimen of *Morula margariticola* (Broderip, 1833) (our concept of *fiscella* Gmelin) under the name *(Cronia crassulnata* (Hedley, 1915), and he (1978, p. 70, pl. 20, fig. 6) illustrates a specimen of *Muricodrupa funiculus* (Wood, 1828) as *Cronia triangulata* (Pease, 1868), which he suggests may prove to be an extreme form of *Cronia fiscella* (Gmelin, 1791).



FIGS. 7a-7b. *Opercular characters (7a, outer surface; 7b, inner surface) of* Muricodrupa fenestrata *(Blainville), greatly enlarged; Truk Lagoon, Moen Island, Caroline Islands, SDSNH 76524.* 8a-8b, *Opercular characters (8a, outer surface; 8b inner surface) of* Muricodrupa funiculus *(Wood), greatly enlarged; Palmyra Island, Line Islands, SDSNH 24188.*

It is our view that *Murex fiscellum* (Gmelin, 1791) should be based on the drawings of Chemnitz *(op. cit.),* which lack any indication of squarish, window-like depressions, and, in the absence of the type specimens, should represent the typological concept of Gmelin's species. Moreover, the descriptive text of Chemnitz *(op. cit.)* could reasonably be applied to several other moruloid species with squarish pits, such as the type species of *Muricodrupa, Purpura fenestrata* Blainville, 1832. Therefore, we interpret *Murex fiscellum* Gmelin to be referable on the basis of Chemnitz's illustrations *(op. cit.)* to the common and wide-ranging Indo-Pacific species subsequently described as *Murex margariticola* Broderip, 1833, p. 177; Reeve, 1846, *Murex* species 178, pl. 34, fig. 178; syntype here illustrated, fig. 9.

This interpretation agrees with the concept of *Murex fiscellum* Gmelin arrived at by Lamarck (1822, p. 346), Blainville (1832, p. 206, pl. 10, fig. 8), and Reeve (1846, *Ricinula* sp. 28, pl. 4, fig. 28), who would qualify as the First Revisor under Article 24 of the International Code of Zoological Nomenclature of the International Congress of Zoology.

In summary, *Muricodrupa jacobsoni,* n. sp. is most closely related to *M. funiculus* (Wood, 1828), [synonyms: *Murex decussatus* Reeve (1845, *Murex* species 153, pl. 31, fig. 153); *Purpura stellaris* Hombron and Jacquinot (1853, atlas, pl. 22, figs. 13, 14); *Coralliophila contragosa* H. and A. Adams (1864, p. 432), and *Sistrum triangulatum* Pease (1868, p. 278, pl. 23, fig. 15)]. Whereas *Cronia fiscella* (Gmelin, 1791), [synonyms: *Murex margariticola* Broderip (1833, p. 177), *Purpura thiarella* Quoy and Gaimard (1833, p. 571, pl. 39, figs. 4–6) [not Lamarck, 1822, p. 246], [?] *Thais crassulnata* Hedley (1915, p. 749, pl. 85, fig. 90), and *Morula rhyssa* Dall (1923, p. 304, a new name for *Ricinula fiscella* Reeve, 1846)], with which the new species also has been confused, is a distinctive species. The type species of the genus-group taxon *Cronia* H. and A. Adams, 1853, *Purpura amygdala* Kiener (1835), apparently has radular morphology (Cooke, 1919, fig. 33) similar to that of the type species of *Muricodrupa.*

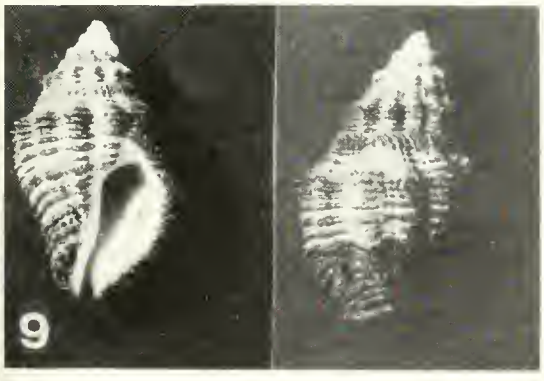


FIG. 9. Murex margariticola *Broderip, one of three syntypes in The British Museum (Natural History),* × 1½; *this specimen is selected as the lectotype. It is a junior synonym of* Cronia fiscella *(Gmelin, 1791).*

ACKNOWLEDGMENTS

We are indebted to the following friends and colleagues for kindly providing specimens for study: Billee Mabry, Richard Salisbury, Thora Whitehead, Emily H. Vokes (Tulane University), Virginia Orr Maes (Academy of Natural Sciences of Philadelphia), and James H. McLean (Los Angeles County Museum of Natural History), who also photographed typological specimens in the British Museum (Natural History). The remaining photographs were taken by Sidney S. Horenstein. William E. Old, Jr., contributed technical assistance.

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NEW RECORDS OF LAND MOLLUSCA IN NEW YORK CITY

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Cecilioides acicula (Müller), a small achatinid snail, has been found in Inwood Hill Park at the extreme northern end of Manhattan Island in New York City. This is the first reported occurrence of this species in New York State.

Specimens of *C. acicula* were discovered along a rocky ridge where the snails were found attached to the undersides of bricks from the ruins of what appears to have been a greenhouse. At this site nine species of shelled pulmonates, in addition to the *Cecilioides,* were found within a few square feet: *Cochlicopa lubrica* (Müller), *Euconulus fulvus* (Müller), *Hawaiia minuscula* (Binney), *Helicodiscus parallelus* (Say), *Oxychilus cellarius* (Müller), *O. draparnaldi* (Beck), *Pupoides albilabris*

(Adams), *Vallonia pulchella* (Müller), and *Vertigo* cf. *ventricosa* (Morse). Several species of slugs have also been recorded. Curiously, *Zonitoides arboreus* (Say), moderately common elsewhere in the park, has not been found here.

Vallonia costata (Müller) was also found in Inwood Hill Park, as well as at other locations in northern Manhattan. These occurrences constitute the first record of this species for Manhattan (New York County), but not for New York City. *V. costata* was not recorded from the New York Metropolitan Area until some 20 years ago when Jacobson and Emerson (1961) reported it from Van Cortlandt Park in the Bronx, but that colony evidently does not exist today. I carefully searched the environs of Van Cortlandt Park without finding *V. costata*. In the *New York Shell Club Notes* for May, 1962 (no. 82) H. S. Feinberg reported *V. costata* from the Riverdale section of the Bronx. I was able to confirm this record at a site some two miles southwest of Van Cortlandt Park in November, 1977. Subsequently, I was able to establish the Manhattan records. *V. costata* is found under stones and fallen logs, and in rock crevices. It occurs in close association with *V. pulchella*. The animals of the two species appear quite similar in their gross aspects, both being white with conspicuous black eye spots.

Specimens of *Cecilioides acicula* and *Vallonia costata*, both from Inwood Hill Park, have been deposited in the American Museum of Natural History (catalog numbers 200375 and 201470 respectively).

I would like to gratefully acknowledge the assistance of the late M. K. Jacobson who read portions of this manuscript and made helpful criticisms. It was he who first suggested that *Cecilioides* might be the correct genus for what proved to be *C. acicula*. I would also like to thank William E. Old, Jr. of the American Museum who granted me access to the Museum's collections and library.

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CORBICULA FLUMINEA, IN LAKE ERIE

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On December 17, 1980, 2 living juvenile specimens of *Corbicula fluminea* (Müller) were collected in the western end of Lake Erie at Monroe, Monroe County, Michigan, by me and by two divers, Messrs. Al Melkic and Ted Creese. This is the first record of *C. fluminea* from the Great Lakes-St. Lawrence drainage system. The specimens both occurred on a sand bottom in 3 feet of water at Sterling State Park, one offshore from a point 1000 feet south of the southern end of a rocky dike near the mouth of Sandy Creek and the other offshore from a point 2000 feet south of the same landmark. The lake level was 2.4 feet above mean low water (MLW) and the specimens were each found while screening the substrate from $3M^2$ bottom samples through a ¼-inch mesh screen. No other mollusks were found in these samples. The specimens were 8.0 and 8.6 mm long, respectively.

C. fluminea probably cannot survive at such shallow depths in Lake Erie because of winter freezing and ice-scouring, but other juveniles from the same 1980 larval settlement probably occur nearby in deeper water. If water temperatures permit, *C. fluminea* will probably now become widespread in the region.

One suspects that the abundant bottom-feeding fishes in Lake Erie will keep *C. fluminea*

populations in the lake itself from becoming too populous and from exerting an adverse effect on native unionid populations. (Where dense populations of *C. fluminea* occur native unionids become rare, perhaps because the filter-feeding activities of *C. fluminea* remove unionid sperm from the water and interfere with unionid reproduction). The eventual damage that *C. fluminea* will cause to water intake systems and other commercial activities in the region, however, may be significant.

LIFE CYCLE OF THE FRESHWATER SNAIL *CAMPELOMA DECISUM* (VIVIPARIDAE) IN THE LABORATORY

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ABSTRACT

Campeloma decisum *reared in Minnesota Lake Superior water grew consistently well when clam meat or commercial fish food was provided and a substrate of sand or mud was present. Food alone, or the substrate alone, was generally ineffective in promoting growth. Thick substrates were more effective than thin substrates. Substrate depth was directly correlated with growth, although some growth occurred when no soft substrate was present.* Campeloma decisum *tested in Missouri hard well water grew equally well with or without a substrate. A population of newborn snails from the St. Croix River, Wisconsin was reared through three generations in 42 months on a diet of clam meat and trout chow with St. Croix River mud substrate. Survival of the original snails to 41 months was 80%.*

Campeloma is an exclusively North American genus of ovoviviparus snails widely distributed in lakes and streams of eastern North America. *Campeloma decisum* (Say, 1819) plays an important role in the fish (Price, 1957) and diving duck (Thompson, 1973) food chains and has been used in studying the effects of toxicants in the laboratory (Arthur, 1970, Arthur and Leonard, 1970).

Arthur and Leonard (1970) studied the effects of a range of copper concentrations on survival, feeding and parturition of young *Campeloma decisum* snails. The snails completely devoured fresh unionid clam meat in copper concentrations of control (2.0 μg/l) up to 8.0 μg/l but would not accept or consume this food at the higher concentrations tested. Although the control snails fed at the rate of one clam per 10 snails per week, there was no measurable growth in 6 weeks. Thus, it was not possible to assess the effects of copper on the ability of the snails to grow and complete the life-cycle. It was believed that experiments to determine why the snails fed without growing would demonstrate a way to grow the snails in the laboratory.

A literature review suggested several explanations for why the snails fed without growing. The following describes several experiments which tested these ideas and ultimately culminated in rearing *Campeloma decisum* through several generations in the laboratory.

Allison (1942) trapped *Campeloma* with dead

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fish or cloth packets of dog, cat, chicken, ferret or muskrat dung. Snails came from both up and down stream, with a maximum number of snails at the trap on the 10th day. Bovbjerg (1952) found populations of *Campeloma decisum* just downstream from rapids in the presence of silt and detritus. In the absence of factors that would orient the snails to food, the snails moved upstream (positive rheotactic response) but the hard surfaces associated with riffles or rapids blocked further upstream movement. Snails moving upstream did not travel over exposed surfaces of rocks. Snails also aggregated on the downstream side of log barriers or boulders.

Thus, the literature reports that *Campeloma decisum* feeds on decayed animal material and cannot function properly on a bare hard surface. In the following experiments *Campeloma decisum* was fed dead clams or other foods under various conditions of hard, sandy, muddy or other substrates. Water quality was also varied to determine the significance of hardness, calcium, or other minerals in growth.

MATERIALS AND METHODS

Effect of Substrate and Food Source

In a study to determine if a soft substrate is needed for growth of snails, young *Campeloma decisum* and various substrates were collected from the St. Croix River, Douglas Co., Wisconsin where the calcium content was 32–37 mg/l as $CaCO_3$. Tests were run for 90 days in flowing carbon filtered water pumped from Lake Superior at Duluth. During the tests, calcium was 46–53 mg/l as $CaCO_3$, temperature 18±1C, dissolved oxygen 8.2–10.2 mg/l, and pH 7.5–8.0.

Ten or 20 snails as available were randomized by size and added to each of 48 10-liter tanks. Substrates provided were either mud or sand, 3.5–4.5 cm deep. Other snails were held in tanks with only glass substrates. Either one 10–15 cm long freshly killed unionid clam or 0.5 gram trout chow (Glencoe starter granules) was provided every 1–2 weeks. Shell lengths were measured with vernier calipers (0.1 mm accuracy).

Tests with Missouri Snails in Hard Water

To determine further if a soft substrate was needed for growth of snails tested in hard water, young *Campeloma decisum* were collected from a muddy substrate in the Gasconade River, Osage Co., Missouri.

Sandy substrate (with some silt and gravel intermixed) was collected from a Gasconade tributary and a layer of this substrate 2.3 cm thick was added to four aquaria each containing 10 snails and 10.3 liters of Columbia, Missouri hard well water (Ca, 70; Mg, 27; K, 3.9; SO_4, 4.4; Cl, 29; EDTA hardness, 272 mg/l).

The water was continuously exchanged at the rate of 0.50–0.52 liters every 4–8 minutes. Four additional control aquaria differed in that no substrate was added to the glass bottom. One dead 10–12 cm freshwater mussel was fed every 3 weeks to the snails in each of two substrate and two control aquaria. This experiment ran from June 19–September 9, 1978 at 18.5–19.3C.

Campeloma Life Cycle

Adult snails were collected in February, 1970 from the St. Croix River, Douglas Co., Wisconsin and placed on a sieved mud substrate in an aquarium at the Duluth Environmental Research laboratory. In August 1970, 30 newborn snails were recovered from this aquarium and placed in an aquarium with sieved mud substrate 3.5–4.5 cm thick. They were fed trout chow with clam meat ad libitum. The snails were provided with flowing Lake Superior water at 18±1C. The mud substrate was exchanged in March 1971, June 1973, and January 1974. Growth rates of the young snails were measured periodically.

RESULTS

Campeloma decisum tested in Duluth, Minnesota soft water grew consistently well when clam or fish food was provided and a substrate of sand or mud was present (Table 1). For example, in one tank with glass substrate and clam meat growth was 0.3 mm (standard error of only 0.09) in 90 days. With mud substrate and clam meat the least growth was 0.8 mm. Food alone, or the substrate alone was generally ineffective in promoting growth. The most growth with mud alone was 0.7 mm. Thick substrates were more effective than thin substrates (Table 2). It

TABLE 1. *Growth in 90 days of* Campeloma decisum *snails (10–20 mm original length) in varied substrates and food sources. Duluth soft water. Each number (except overall average) is average growth (mm) of 10 or 20 snails.*

Substrate provided	FOOD SOURCES None	Clam	$S_{\bar{x}}$	Fish Food
Glass	0.0	0.0		0.1
		0.0		0.2
		0.1		0.2
		0.1		0.2
		0.2		0.7
		0.3	0.09	0.8
		0.4		1.0
		0.6		2.0
		0.8		
		1.0		
		1.2		
		0.4	0.05	0.65
Mud	0.0	0.8	0.25	2.1
	0.0	0.9	0.12	
(St. Croix River)	0.0	1.0	0.25	
	0.1	1.0	0.19	
	0.1	1.1	0.28	
	0.1	1.3	0.33	
	0.1	1.3	0.31	
	0.2	1.3	0.15	
	0.2			
	0.3			
	0.7			
	0.16	1.1	0.079	
Sand	0.1	0.7	0.17	
	0.1	0.7	0.22	
(St. Croix River)	0.0	0.9	0.23	
		1.0	0.21	
		1.3	0.33	
	0.07	0.9	0.10	

TABLE 2. *Growth in 90 days of* Campeloma decisum *snails (10–20 mm original length) in varied St. Croix River mud substrate depths and food sources. Duluth soft water. Each number is average growth (mm) of 10 snails.*

Substrate provided	FOOD SOURCE None	Clam	$S_{\bar{x}}$	Fish Food	$S_{\bar{x}}$
Glass	0.0	0.5		1.5	
	0.0	0.5		1.1	
	0.0	0.7		1.1	
		0.57	0.098	1.23	0.10
1.0 mm	0.0	1.2		2.8	
	0.0	1.5		1.5	
	0.0	1.1		1.8	
		1.27	0.11	2.0	0.17
5.0 mm	0.0	1.8		3.3	
	0.0	1.3		3.4	
	0.0	1.4		3.2	
		1.5	0.15	3.3	0.26
25.0 mm	0.0	2.1		3.2	
	0.0	2.2		3.7	
	0.0	2.5		2.6	
		2.27	0.17	3.17	0.17

TABLE 3. *Growth of young Missouri snails June 9–September 19. Missouri hard water. 18.5–19.3C.*

Substrate	Food	Initial No.	Initial length	mm growth 102 days	$S_{\bar{x}}$	Final No. Alive
Sand	none	10	10.4 - 12.9	0.0		10
"	"	10	13.2 - 15.8	0.0		10
Glass	none	10	8.7 - 12.0	0.0		10
"	"	10	12.8 - 15.0	0.0		10
Glass	clam	10	9.7 - 12.9	2.0	0.34	10
"	"	10	13.7 - 16.0	2.3	0.38	9
Sand	clam	20	9.8 - 16.2	2.4	0.27	12

TABLE 4. *Mean length and number of survivors for several generations of* Campeloma decisum. *The first generation produced at least three second generations. The first of these in turn produced a third generation.*

Date	First Generation			Second Generation			Second Generation			Second Generation			Third Generation		
	N	Age (months)	length (mm)	N	Age (months)	length (mm)	N	Age (months)	length (mm)	N	Age (months)	length (mm)	N	Age (months)	length (mm)
August 1970	30	0	newborn												
January 1972	29	17	18.3	27	0	3.5									
January 1973	28	29	23.1												
March 1973				21	14	10.9									
September 1973	27	37	23.7	14	20	17.4	30	6	7.0						
January 1974	24	41	24.4	15	24	18.8	30	10	9.0	30	3	4.9			
February 1974													34	0	3.5
June 1974	17	46	25.1	15	29	20.9	30	15	13.6	29	8	7.0	10	4	4.5

s seen that substrate depth was directly correlated with growth, although some growth occurred without any soft substrate. The survival rate was 80–100% per tank.

Campeloma decisum tested in Columbia, Missouri hard water grew equally well with or without substrate (Table 3). A population of newborn snails from the St. Croix River, Wisconsin was reared through three generations in 42 months on a diet of clam meat and trout chow with St. Croix River mud substrate (Table 4).

DISCUSSION

The demonstrated synergistic action of food and natural sand or mud substrate on growth of *Campeloma decisum* in the laboratory is probably related to the preference of this species for sand or mud substrate in the wild.

Further experimentation is required to determine if the synergistic property of the substrate was a mineral such as calcium, a vitamin, sand grain digestive aid, protection from harmful wavelengths of light, or a "psychological requirement." It is not known if the lack of synergistic action of soft substrate and food for Missouri snails in Missouri hard water was due to calcium in the hard water or genetic differences from the Wisconsin snail population. Chamberlain (1958) cultured 45 North Carolina

Campeloma decisum "in isolation" in 4.5 inch fingerbowls containing a natural substrate of clayey silt with some sand and decaying organic debris. They grew at about the same rate as in nature but only two snails were still alive after 12 months. He found that *Campeloma decisum* from University Lake, Chapel Hill, North Carolina were not gravid before two years of age and until reaching 15.0 mm in length. The largest snail he collected was 27.3 mm long. The second year class lost identity as a size class at 20 mm in length. The parturition period was from mid-March until the end of June.

Medcof (1940) who studied *Campeloma decisum* from the Speed River, Ontario, also reported that sexual maturity was reached in two years, and one, two, and three year old snails were 12, 17 and 23 mm long, respectively. The parturition period was from March–September. From Table 4 it may be noted that newborn snails (August 1970) reproduced in less than two years (January 1972, about 17 months after birth) presumably due to early parturition in the laboratory. The approximate maximum length (25.1 mm) obtained by snails in our study was similar to that found by Medcof (23 mm) and Chamberlain (20–27.3 mm).

ACKNOWLEDGMENTS

Dr. Henry van der Schalie, University of Michigan Museum and department of Zoology, and Dr. Carol B. Stein, Ohio State University Museum of Zoology, identified *Campeloma decisum* from Wisconsin and Missouri, respectively. Virginia Vail reviewed the manuscript.

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NEWS

Dr. Arthur E. Bogan joined the staff of the Department of Malacology, Academy of Natural Sciences of Philadelphia in September 1980. He came to the Academy having received his doctorate from the University of Tennessee, Knoxville. His thesis was concerned, in part, with Unionidae in archaeology. His position, curatorial associate, involves management of the growing computerized collection data base, generating reports from the data base such as: *Catalog of the Chiton Types* (1979; Tryonia, 1:1–60), identification of species, curatorial updating of families, processing new collections for cataloging. Dr. Bogan joins Drs. Davis and Robertson in managing the neontological and paleontological sections of the Department of Malacology. The collections are supported, in part, by a continuing grant from the National Science Foundation.

The **Western Society of Malacologists** will hold its 14th annual meeting June 23–26, 1981, at the San Diego State University. The **American Malacological Union** will hold its 50th anniversary meeting July 19–24, 1981, in Ft. Lauderdale, Florida (details Jan. issue of *The Nautilus*, p. 37). The 1981 convention of the **Conchologists of America** will meet in San Francisco, California Sept. 2–5 at the Miyako Hotel in the Japan Center.

THE NORTHERN EXTENSION OF THE RANGE OF *ANODONTA SUBORBICULATA* SAY (BIVALVIA: UNIONIDAE)

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ABSTRACT

The naiad mollusk, Anodonta suborbiculata *Say, 1831, has apparently never been reported alive in the Mississippi River main stem north of Fairport, Iowa (River Mile 463). During 1977 two live specimens were collected in Bluff Slough, at La Crosse, Wisconsin. Because of the obvious age difference in these specimens, reproduction in the area seems likely. Three other living naiad species and four dead naiad species were also collected from this site.*

The naiad mollusk *Anodonta suborbiculata* Say, 1831, popularly known as the Heel-Splitter or Flat Floater, has apparently never been reported alive from the Mississippi River main stem above Fairport, Iowa (River Mile 463) (Coker, 1919), nor in the Illinois River north of Peoria Lake (Danglade, 1914).

Witter (1883), in reporting on the mollusca of Muscatine County (Iowa), stated that *A. suborbiculata* was "common or even abundant, in Keokuk Lake, and lakes along Cedar (River), especially the lake on the west bank of Cedar, a half-mile below Moscow" (Iowa). Studies of the Mississippi River since the 1920's have not reported this species (Dr. M. M. Ellis (summarized by van der Schalie and van der Schalie, 1950), Dawley (1947), Coon et al. (1977), Havlik and Stansbery (1978), Fuller (1978), Perry (1979) and Havlik and Marking (1981)).

Apparently *A. suborbiculata* was never found in Wisconsin (Baker, 1928, and H. Mathiak, per. comm., Horicon, Wisconsin). Several studies of the Mississippi, Minnesota River and Black Rivers by the author have not revealed this species.

During June 1977 two live specimens of *A. suborbiculata* were taken from Bluff Slough, Pool 8 of the Mississippi River at La Crosse, Wisconsin. This 90-meter-wide side channel, at Mississippi River Mile 695, was being investigated by the author as part of an environmental assessment for a sewer line to be constructed under the Slough by the city of La Crosse.

The two living specimens, about 5 and 8 years of age, were in 1.5 meters of water on a sand bar that also contained some soft to firm mud, about 15 meters downstream from the proposed sewer line. Because of the obvious age and size difference, reproduction in the area seems likely, at least on a limited basis. One specimen is in the Ohio State University Museum of Zoology, Columbus, Ohio 43210 (OSUM:1977:398:42780).

Other naiad species collected alive at this site included *Anodonta grandis corpulenta* Cooper, 1834, *Amblema plicata plicata* (Say, 1817) and *Fusconaia flava* (Rafinesque, 1820). Dead specimens were found of *Lampsilis radiata luteola* (Lamarck, 1819) and *L. ventricosa* (Barnes, 1823); sub-fossil specimens were found of *Lasmigona complanata* (Barnes, 1823) and *Leptodea fragilis* (Rafinesque, 1820). No rare or endangered species were found.

Very few recent records exist for this species in the Upper Mississippi River. Two additional Wisconsin records for *A. suborbiculata* in the Mississippi River backwaters have been reported. A single fresh-dead specimen was found August 1978 at Mississippi River Mile 637.4, Pool 10, on the shore of an area known as Big Lake, 3.2 kilometers north of Prairie du Chien, Wisconsin (James Theler, per. comm. Dept. of Anthropology, University of Wisconsin-Madison, Madison, Wisconsin). Theler also found several other fresh-dead *A. suborbiculata* in the same general area June 1980. These specimens are all at The Ohio State University Museum of Zoology.

Fresh-dead shells of *A. suborbiculata* were found in 1976 in a then dried-up, small pond on the southern tip of Arsenal Island bordering Sylvan Slough, and in two other locations in Sylvan Slough in 1977 at Rock Island, Illinois, Mississippi River Mile 482.8 (Thomas Freitag, per. comm., Rock Island District, Corps of Engineers, Rock Island, Illinois).

Four recently-dead shells were found in 1978 in water 0.75 meters deep in about a 2 hectare pond, about 10.4 kilometers NW of Muscatine, Iowa (Michael Knott, per. comm., Stanley Consultants, Inc., Muscatine, Iowa).

Apparently this species is more common in the Upper Mississippi River than formerly believed, but the favored habitat makes collection difficult.

ACKNOWLEDGMENTS

I wish to thank Dr. David H. Stansbery and Dr. Carol B. Stein for their comments on the early draft of this paper, and Leif Marking, National Fishery Research Laboratory, La Crosse, Wisconsin, for his comments on the final manuscript.

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SOME PERUVIAN HYDROBIIDS, POTENTIAL SNAIL HOSTS OF PARAGONIMIASIS

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Paragonimiasis, a lung fluke infection, is common among humans and/or animals in the Far East, Southeast Asia, West Africa and the Americas. According to Abbott (1948) thiarids (melaniids), pleurocerids or assimineids are the usual snail first intermediate host in the Far East, but 3 out of 17 species of lung flukes there utilize hydrobiids. In West Africa the snail host is a thiarid. It has been established that hydrobiids (family Hydrobiidae) act in this capacity in the Americas. While it has been known for some time that the amphibious *Pomatiopsis lapidaria* Say is the snail host of *Paragonimus kellicotti* in the United States (Ameel, 1934), only during the last decade did it become known that the small aquatic *Aroapyrgus colombiensis* is the snail host of *P. caliensis* in Colombia (Malek and Little, 1971) and that *Aroapyrgus costaricensis* (Mörch, 1861) is the snail host of *P. mexicanus* in Costa Rica (Malek et al., 1975).

Although the etiologic agent of human paragonimiasis in Peru and Ecuador is not known, it is very likley that one or all of *P. peruvianus, P. amazonicus* and *P. caliensis,* which infect animals in Peru, also causes the disease in humans. The snail hosts of *Paragonimus* spp. in Peru and Ecuador are still not known. However, on account of similarities in the biology and details of the life cycle of the lung flukes in Central and South America, we believe that the snail hosts of paragonimiasis in Peru and Ecuador are also small aquatic hydrobiids, as they are in Colombia and Costa Rica.

Among snails collected by the junior author in Peru in 1960 and 1961 are some small aquatic hydrobiids which we consider to be potential hosts of lung flukes in Peru and possibly also in Ecuador. These hydrobiids are: (1) *Aroapyrgus colombiensis* Malek and Little, 1971, Fig. 1A. This species was collected from streams at Jacos, Trujillo, Peru. *Potamopyrgus mirandoi*

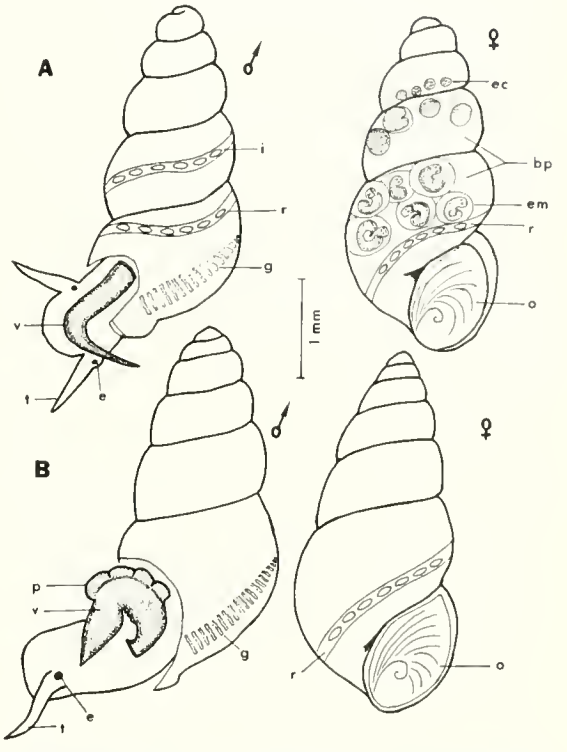

FIG. 1. **A,** Aroapyrgus colombiensis *Malek and Little, 1971, male and female.* **B,** Littoridina cumingii *(Orbigny, 1835), male and female. Some internal organs show through the transparent shell especially the embryos in the ovoviviparous female* A. colombiensis. *In the male, part of the shell broken to expose verge.* **bp,** *brood pouch;* **e,** *eye;* **ec,** *egg capsule;* **em,** *embryo;* **g,** *gill;* **i,** *intestine;* **o,** *operculum;* **p,** *papilla on verge;* **r,** *rectum;* **t,** *tentacle;* **v,** *verge.*

Weyrauch, 1963, described as a new species in Peru on the basis of the shell only, is probably this species. (2) *Littoridina cumingii* (Orbigny, 1835) Fig. 1B. This species was collected from streams near Lima, Peru. Orbigny (1835, 1835–1846) based his description of the shell on material collected near Callao and Lima, Peru and at Valparaiso, Chile. Our bases for identification of these two hydrobiids are the shell,

the operculum, the verge, details of the female reproductive system and the radula.

Aroapyrgus colombiensis has a similar habitat in Peru as in Colombia, where it is the natural host of *P. caliensis*. The purpose of this short paper is to stimulate parasitologists to look for natural infections with *Paragonimus* spp. among hydrobiids in Peru and Ecuador, and to attempt to infect them experimentally. It should be noted that thiarids, in the same habitats with *A. colombiensis* in Colombia, are not infected with the lung flukes.

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FRESHWATER NAIADES OF EAGLE CREEK, A TRIBUTARY OF THE KENTUCKY RIVER (UNIONIDAE)

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ABSTRACT

A survey of the freshwater Naiades of Eagle Creek, a tributary of the Kentucky River, was carried out during the summer of 1980. Ten stations were collected at irregular intervals during the summer. A total of twenty-one species are reported as currently occurring in the stream. Two species, Pleurobema clava *and* Cyclonaias tuberculata, *may no longer be present in the stream as they were found only as dead shells. All other species enjoy wide-spread distribution and good numbers are present.* Anodontoides ferussacianus, Simpsonaias ambigua *and* Elliptio crassidens *are reported for the first time as occurring in the Kentucky River system.*

As part of a continuing effort to document freshwater mussel faunal assemblages of smaller Kentucky streams, this paper reports work carried out during the summer of 1980 on Eagle Creek, a major downstream tributary of the Kentucky River. Eagle Creek enters the Kentucky River near the village of Worthville, Carroll County, Kentucky, at a point some seven miles from the confluence of the Kentucky with the Ohio River at Carrollton, Kentucky (Fig.1). The Kentucky River proper originates in the mountains of eastern Kentucky which are located within the Cumberland Plateau. The headwaters consist of three main branches, the North, Middle and South Forks. Three additional major tributaries flow into the Kentucky River along its 400 mile length. They are: (1) the above-mentioned Eagle Creek, (2) the Dix River and (3) the Red River.

The only previous study concerned with the freshwater naiades of this drainage was carried out by Danglade (1922) some 60 years ago. During the summers of 1919–1920, he surveyed the mussel resources of the mainstem Kentucky River with an eye on the commercially valuable shells which fed the burgeoning shell-button industry. In 1920, a single 35 mile stretch of river, which he monitored regularly, produced 87 tons of desirable shells. A total of 40 species of mussels (22 with commercial value) was reported as occurring in the drainage (Table 1). These data indicate a productive stream of good water quality and readily available suitable habitat. Since the studies of Danglade the river has been modified. Extensive "improvements"

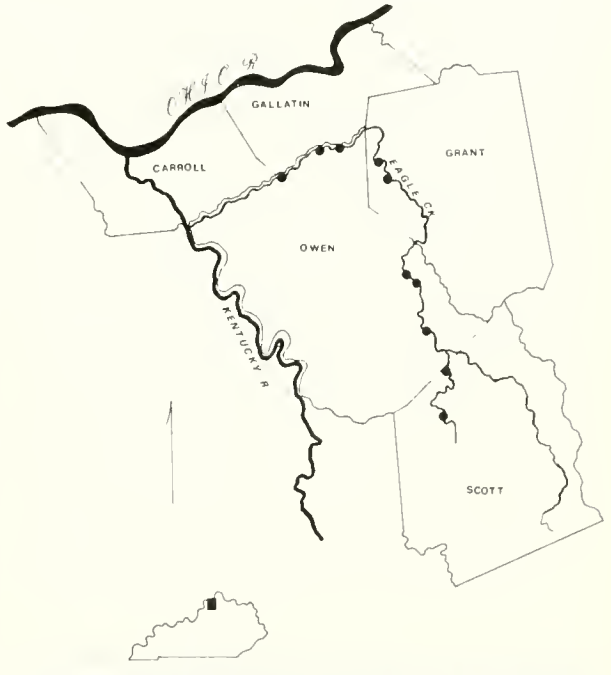

FIG. 1. *Map of northern central Kentucky showing collecting stations (black dots) on the Eagle Creek.*

TABLE 1. *Freshwater Naiades of Kentucky River as Reported by Danglade (collected summers of 1919–1920).*

Name as used by Danglade	Name in current usage
Alasmidonta marginata	Alasmidonta marginata Say, 1818
Alasmidonta minor	Alasmidonta viridis (Raf., 1820)
Anodonta grandis	Anodonta g. grandis Say, 1829
Anodonta imbecillis	Anodonta imbecillis Say, 1829
Lyprogenia irrorata	Lyprogenia stegaria (Raf., 1820)
Lampsilis alata	Potamilus alatus (Say, 1817)
Lampsilis anodontoides	Lampsilis teres form anodontoides (Lea, 1841)
Lampsilis fallaciosa	Lampsilis teres form teres (Raf., 1820)
Lampsilis gracilis	Leptodea fragilis (Raf., 1820)
Lampsilis ligamentina	Actinonaias ligamentina carinata (Barnes, 1823)
Lampsilis luteola	Lampsilis radiata luteola (Lam., 1819)
Lampsilis multiradiata	Lampsilis fasciola Raf., 1820
Lampsilis parva	Toxolasma parvus (Barnes, 1823)
Lampsilis recta	Ligumia recta (Lam., 1819)
Lampsilis ventricosa	Lampsilis ventricosa (Barnes, 1823)
Obliquaria reflexa	Obliquaria reflexa Raf., 1820
Obovaria subrotunda	Obovaria subrotunda (Raf., 1820)
Plagiola donaciformis	Truncilla donaciformis (Lea, 1827)
Plagiola elegans	Truncilla truncata Raf., 1820
Pleurobema clava	Pleurobema clava (Lam., 1819)
Ptychobranchus phaseolus	Ptychobranchus fasciolaris (Raf., 1820)
Quadrula coccinea	Pleurobema sintoxia (Raf., 1820)
Quadrula cylindrica	Quadrula cylindrica cylindrica (Say, 1817)
Quadrula granifera	Cyclonaias tuberculata (Raf., 1820)
Quadrula heros	Megalonaias nervosa (Raf., 1820)
Quadrula kirtlandiana	Fusconaia maculata kirtlandiana (Lea, 1854)
Quadrula lachrymosa	Quadrula quadrula (Raf., 1820)
Quadrula pustulata	Quadrula nodulata (Raf., 1820)
Quadrula pustulosa	Quadrula pustulosa pustulosa (Lea, 1831)
Quadrula rubiginosa	Fusconaia flava (Raf., 1820)
Quadrula solida	Pleurobema cordatum (Raf., 1820)
Quadrula subrotunda	Fusconaia maculata maculata (Raf., 1820)
Quadrula undulata	Amblema plicata plicata (Say, 1817)
Strophitus edentulus	Strophitus undulatus undulatus (Say, 1817)
Symphynota complanata	Lasmigona complanata (Barnes, 1823)
Symphynota costata	Lasmigona costata (Raf., 1820)
Tritogonia tuberculata	Tritogonia verrucosa (Raf., 1820)
Truncilla rangiana	Epioblasma torulosa rangiana (Lea, 1839)
Truncilla triquetra	Epioblasma triquetra (Raf., 1820)
Unio gibbosus	Elliptio dilatata (Raf., 1820)

for navigational purposes have been made, and additionally the stream has suffered from man's other activities in the last 80 years (i.e., mining, industry, agriculture and sewage).

Eagle Creek, on the other hand, remains essentially unchanged today. There are no dams, no industries and only limited human sewage input along the Ca. 80 mile length of the stream. Eagle Creek originates in the Bluegrass region of central Kentucky just north of Lexington and flows in a northwesterly direction through rolling knobs past horse and tobacco farms to the Kentucky River. No towns of appreciable size exist within the drainage of this creek. The creek for the most part never exceeds 15 m in width or 2 m in depth.

METHODS

Ten stations, where good naiad populations existed, were established and visited at irregular intervals throughout the summer of 1980. Shells were hand picked from the shallows. Additionally fresh dead valves, deposited as middens by muskrats and raccoons, are included in Table 2. Specimens found only as dead, badly eroded shells are indicated as such. The material collected was returned to the laboratory, cleaned, identified and catalogued in the Marshall University Malacological Collections. Dr. David H. Stansbery of the Ohio State University Museum of Zoology very kindly confirmed identifications of some specimens. Voucher specimens have been placed with O.S.U.M. All names included herein are those used by Stansbery (1979).

Collecting Site Localities

1. Scott Co.–Co. Rd. 620 at Porter Rd. near Salem Church.
2. Scott Co.–Pokeberry Rd., ¾ mi. W of I-75 near village of Sadieville.

TABLE 2. *List of species found at each location, Eagle Creek, Kentucky 1980 Survey. (C) = common, (M) = moderately common, (R) = rare.*

Species	Localities									
	1	2	3	4	5	6	7	8	9	10
Anodonta g. grandis Say, 1829 (C)	X	X	X	X	X	X	X	X	X	X
Anodontoides ferussacianus (Lea, 1834) (R)					X					
Strophitus u. undulatus (Say, 1817) (C)		X		X	X	X	X	X	X	X
Alasmidonta viridis (Raf., 1820) (C)				X	X	X	X	X	X	X
Simpsonaias ambigua (Say, 1825) (M)							X	X		
Lasmigona complanata (Barnes, 1823) (C)					X	X		X	X	
Lasmigona costata (Raf., 1820) (R)							X			
Tritogonia verrucosa (Raf., 1820) (C)						X	X	X	X	
Quadrula quadrula (Raf., 1820) (M)							X	X	X	X
Amblema p. plicata (Say, 1817) (M)						X	X	X	X	
Fusconaia flava (Raf., 1820) (M)					X		X	X	X	
Cyclonaias tuberculata (Raf., 1820)* (R)								X	X	
Pleurobema clava (Lam., 1819)* (R)								X		
Elliptio c. crassidens (Lam., 1819) (R)								X		
Elliptio dilatata (Raf., 1820) (C)				X	X	X	X	X	X	X
Ptychobranchus fasciolaris (Raf., 1820) (M)							X		X	
Leptodea fragilis (Raf., 1820) (M)				X	X			X	X	
Potamilus alatus (Say, 1817) (C)					X	X	X	X	X	X
Toxolasma parvus (Barnes, 1823) (R)				X						
Lampsilis r. luteola (Lam., 1819) (C)		X	X	X	X	X	X	X	X	X
Lampsilis ventricosa (Barnes, 1823) (C)				X		X	X	X	X	X

*Found only as badly eroded dead shells

3. Owen Co.–Co. Rd. 1883, 1 mi. NW of Jct. with Co. Rd. 2018, 2 mi. W of village of Natlee.
4. Owen Co.–Co. Rd. 1739, behind Mussel Shoals Baptist Church, 1.5 mi. NE of Jct. with St. Rd. 845.
5. Owen Co.–Jct. of St. Rd. 330 at St. Rd. 845 under bridge, area locally known as Lusby's Mill (old milldam still present).
6. Grant Co.–Co. Rd. 1132, 1.5 mi. N of Jct. Calendar Rd., 3 mi. N of village of Jonesville.
7. Grant Co.–Co. Rd. 1132, 1.5 mi. S of Jct. with St. Rd. 467 at Ford's Mill Rd.
8. Gallatin Co.–St. Rd. 467, 4.2 mi. E of village of Sparta, 1.2 mi. W of Glencoe.
9. Gallatin Co.–St. Rd. 467, 1.2 mi. ENE of village of Sparta at Louisville and Nashville Railroad crossing.
10. Owen Co.–St. Rd. 35, under bridge at Sparta.

RESULTS

Twenty-two species of freshwater naiades were found in Eagle Creek (Table 2). Two species, *Cyclonaias tuberculata* and *Pleurobema clava*, were found only as badly eroded dead shells and may be assumed to be either very rare or no longer present in this stream. *Anodontoides ferussacianus*, *Simpsonaias ambigua*, *Lasmigona costata*, *Elliptio crassidens* and *Toxolasma parvus* were found only rarely. All other species were found widely distributed and in fairly good numbers throughout most of the stream. *Anodonta g. grandis* was found at every station and *Lampsilis r. luteola* was found at every station except Station No. 1.

Anodontoides ferussacianus, *Simpsonaias ambigua* and *Elliptio crassidens* are reported herein for the first time as occurring in the Kentucky River system.

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CONCLUSIONS

The Kentucky River around the turn of the Twentieth Century was a stream of relatively high quality and supported a freshwater naiad population of considerable commercial value (Danglade, 1922). Whether that is still the case remains to be seen. Future investigators may wish to take a second look at the Kentucky and see what effects habitat modifications (i.e, pollution, damming, etc.) have had. One must assume that as in other comparable streams the impact has been great. I would be very surpised if any single location in the Kentucky still supported mussels in commercial quantities. I would also be surprised if many of the species reported by Danglade were still in the river, even in limited numbers. Among this doubtful group would be *Quadrula cylindrica*, *Actinonaias l. carinata*, *Lampsilis teres*, *Pleurobema clava*, *Epioblasma t. rangiana* and *Epioblasma triquetra*.

The future outlook for our larger streams is not one of total dispair. It may well be that if and when the larger streams are cleaned up, to a point where they again afford suitable habitat for naiades, lesser tributaries such as Eagle Creek may produce the restocking material for these larger waterways.

The large number of species and good numbers of individuals in Eagle Creek indicate a stream of rather high quality that is under little or no environmental stress. Conservation efforts by state and federal agencies, aimed at protecting these small stream refugia, may be the key to the continued existence of freshwater naiades in North America.

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A NEW SPECIES OF *CROSSLANDIA* (NUDIBRANCHIA: DENDRONOTACEA) FROM THE GULF OF CALIFORNIA

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Members of the dendronotacean nudibranch family Scyllaeidae have been reported throughout the equatorial and temperate seas for over two centuries. Seba (1743) first published an illustration of one of these species as *Pullus Ranae Piscatricis Quartae.* He thought is was the young of a fish and figures it in an inverted position. Several years later, Linnaeus (1758) named this species *Scyllaea pelagica,* thus establishing the binomial. Linnaeus, however, continued the error of describing the animal upside down.

Presently, Scyllaeidae contains three genera: *Scyllaea* Linnaeus, 1758, *Crosslandia* Eliot, 1902, and *Notobryon* Odhner, 1936. Characteristics of the genera are detailed in Odhner (1936: 1096–1103).

Crosslandia daedali Poorman and Mulliner, new species

Description—Body long, about 25 mm in length, narrow and deep; produced forward in a long neck and posteriorly in a short tail (Fig. 1). Wide winglike lobes extended laterally along the middle one-half of each side; lobes irregularly notched and digitate (Fig. 2). Head blunt, with an abbreviated vellum on upper portion of the buccal opening. Rhinophores retractile in hollow of flaring rhinophore sheaths; conical, perfoliate with 22 leaves. Numerous fimbriating retractable branchial tufts irregularly placed on the inside surface of the lobes and the dorsal area between (Fig. 2). A caudal crest extended over the tail section.

Color of animal greenish brown-orange; longitudinal fine chestnut brown lines with some white lines on sides and undersides of lobes; a

FIG. 1. *Sketch of a living* Crosslandia daedali *(25 mm in length) crawling over* Padina; *lateral view, anterior to the right. Drawing by A. D'Attilio.*

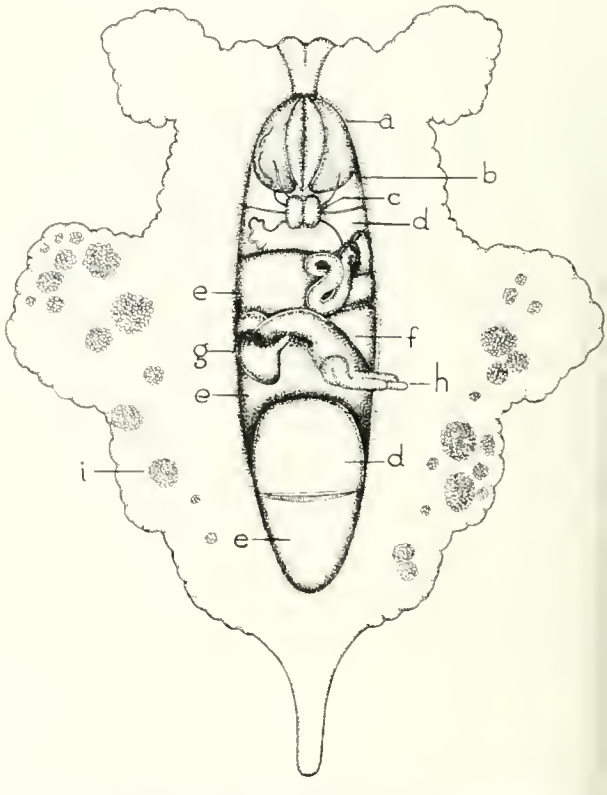

FIG. 2. *Dorsal view of* Crosslandia daedali, *showing the branchiae on the inner surface of the body lobes and various internal organs.* **a**, *jaw plates;* **b**, *pharyngeal bulb;* **c**, *ganglion;* **d**, *liver mass;* **e**, *three-part hermaphroditic gland;* **f**, *stomach;* **g**, *heart;* **h**, *anus;* **i**, *branchial tufts. Drawing by A. D'Attilio.*

[1]15300 Magnolia Street, Sp. 55, Westminister, CA 92683.

narrow light-colored border along the thin edge of the rhinophore sheaths, along the sides of neck, around edge of lobes and crest of tail; irregular black to brown blotches on some animals. Brilliant blue small round spots medially along sides of body, about 6 in number, about 5 spots medially on the dorsum, most spots with fine black borders. A row of 4–6 flesh-colored, sharply conical tubercles along median line of each side of the animal.

Jaw plates (Fig. 3) large and hinged dorsally with the muscles attached at the bend and

FIG. 3. *Lateral view of the jaw of* Crosslandia daedali. *Drawing by A. D'Attilio.*

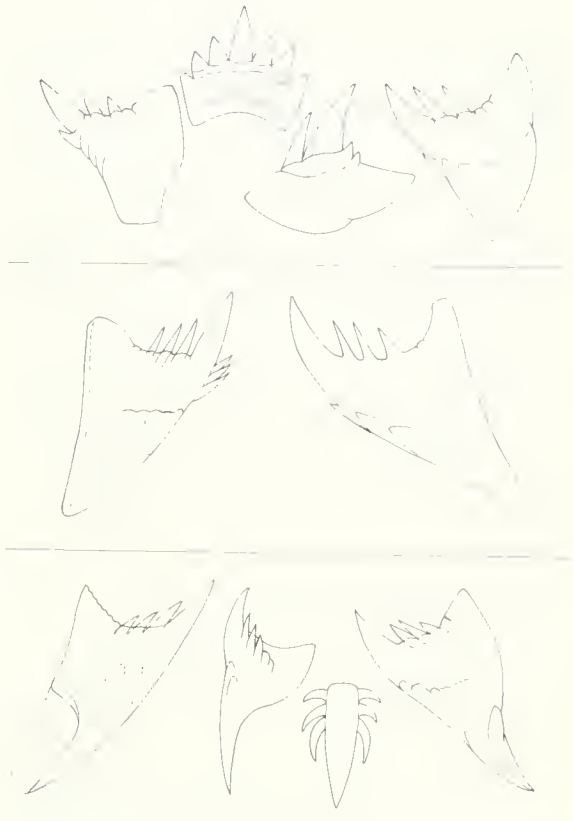

FIG. 4. *Sketches of various views of assorted radular teeth. Drawings by A. D'Attilio.*

covering the large tessellated stiff cheeks. The radula with 15 longitudinal rows of teeth denticulated on both sides (Figs. 4 and 5); central tooth slightly flattened, smaller than the laterals. The radula formula 15×25•1•25.

The hermaphrodite gland (Fig. 6) of three masses, two posterior, one on each side of a liver mass located in the mid-dorsal region; the third mass located anterior on the right side of the animal. The genital opening beneath the rhinophore sheath on the right side. The spermatheca connecting directly into the vagina. The large ampulla connected by a long convoluted tube to the genital orifice. The liver in two large masses anterior and posterior. The stomach armed with 14 plates in a constricting ring. The anus located midpoint of the side below the right lobe.

Type-locality–Tinajas, Bahia de Bacochibampo, Sonora, Mexico (27°56′N; 110°59′W).

Material examined–Holotype, San Diego Natural History Museum, Department of Marine Invertebrates, Type Series No. 514. Collected at Tinajas, Bacochibampo Bay, Sonora, Mexico (27°56′N; 110°59′W); 4 December 1975, by Roy and Forrest Poorman. Paratypes, collected with the holotype specimen, are deposited in the malacology (or marine invertebrate) collections of the San Diego Natural History Museum (SDNHM Type Series No. 515), the Los Angeles County Museum of Natural History (LACM 1910), and the United State National Museum (USNM 795112).

Additional material was collected at Tinajas, Sonora, Mexico, on 23 October 1976. Also, 4 specimens were collected at Bahia de Algodones, Sonora, Mexico, and 1 specimen was collected on the east side of Punta Cuevas, Bahia de San Carlos, Sonora, Mexico.

Etymology–This species is named in recognition of the Greek, Daedalus. When the animal is at rest, it attaches to *Padina* with the posterior part of the foot. With its lateral lobes extended

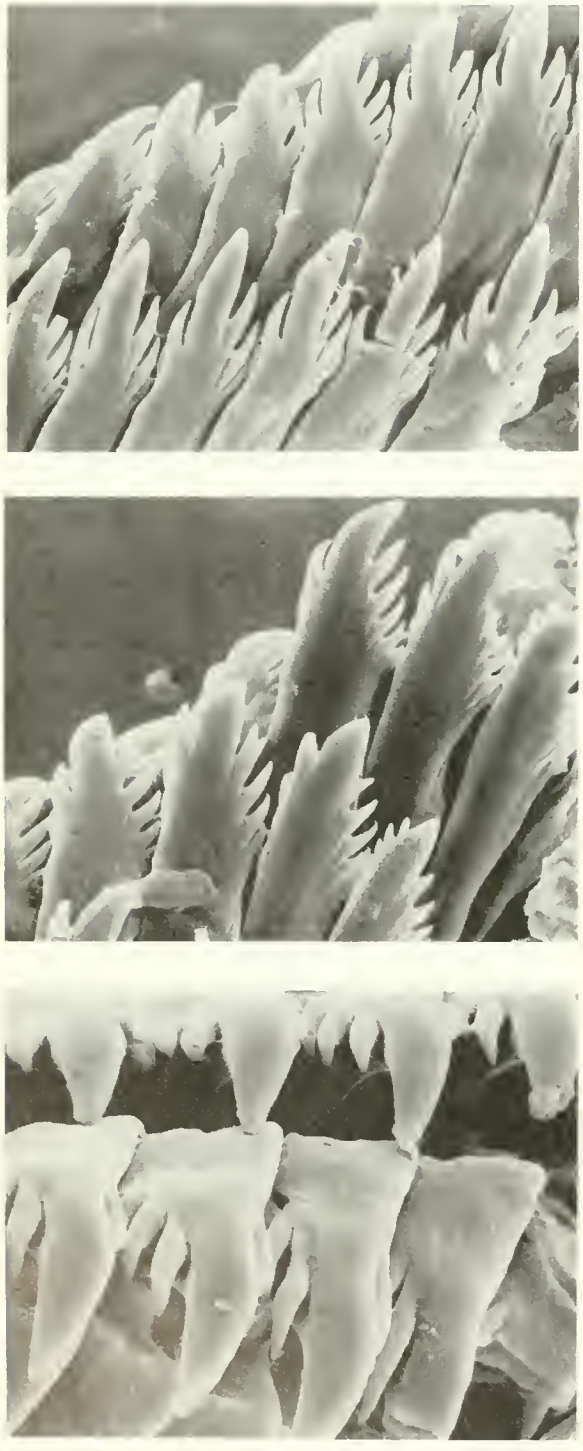

FIG. 5. *Scanning electron micrographs of the lateral teeth of* Crosslandia daedali. *Top and middle, approximately 635×. Bottom, approximately 1300×. Microscopy by Robert Pettyjohn.*

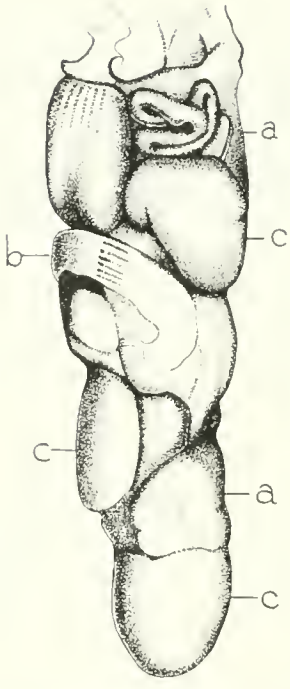

FIG. 6. *Sketch of the viscera of* Crosslandia daedali. **a,** *liver mass;* **b,** *stomach;* **c,** *hermaphroditic gland. Drawing by A. D'Attilio.*

and head and neck raised, it appears to reach outward from the stem. Just so must the legendary Daedalus have looked as he fastened on his feathers and paused before launching into his winged flight.

DISCUSSION

Crosslandia daedali has been found only on the Sonoran shores of the Gulf of California, in the Guaymas area. It is the first record of the genus from the Eastern Pacific. Its known congener, *C. viridis* Eliot, 1902, has been reported only from Zanzibar, the Red Sea and Japan.

There are distinctive internal anatomical features which distinguish these two species. In *Crosslandia daedali* the masticatory edge of the jaws is smooth and flexible, bending outward and forming stiff cheeks which are attached full length. By contrast, a slit separates the bottom one-third of the jaw plate at the bend in *C. viridis*. The spermatheca of *C. daedali* is attached directly to the vagina, whereas in *C. viridis* it is connected by a long tube.

Externally, the new species consistently

shows a narrow, light-colored border along the sharp edges of the body and all the appendages. This is not apparent on *Crosslandia viridis*.

Crosslandia daedali consumes small hydroids growing on the surface of the algae. The nudibranchs graze slowly over the surface or attach to the stems with a small central portion of the foot, resting with the head and neck extended and the lateral lobes projecting at an angle of about 45° from the vertical. Because of coloring and irregular shape, these animals are mimetically camouflaged, resembling another piece of torn algae.

ACKNOWLEDGMENTS

We thank Mrs. Laura Shy for field assistance; Mr. Robert Pettyjohn for doing the scanning electron microscopy; Mr. Anthony D'Attilio (Department of Marine Invertebrates, San Diego Natural History Museum) for the anatomical drawings; and especially Dr. Hans Bertsch (formerly Curator of Marine Invertebrates at the San Diego Natural History Museum) for his editorial assistance in putting this paper together.

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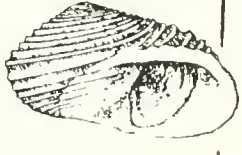

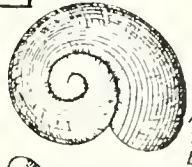

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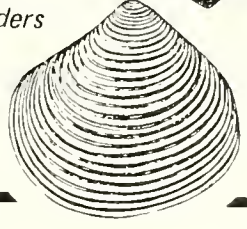

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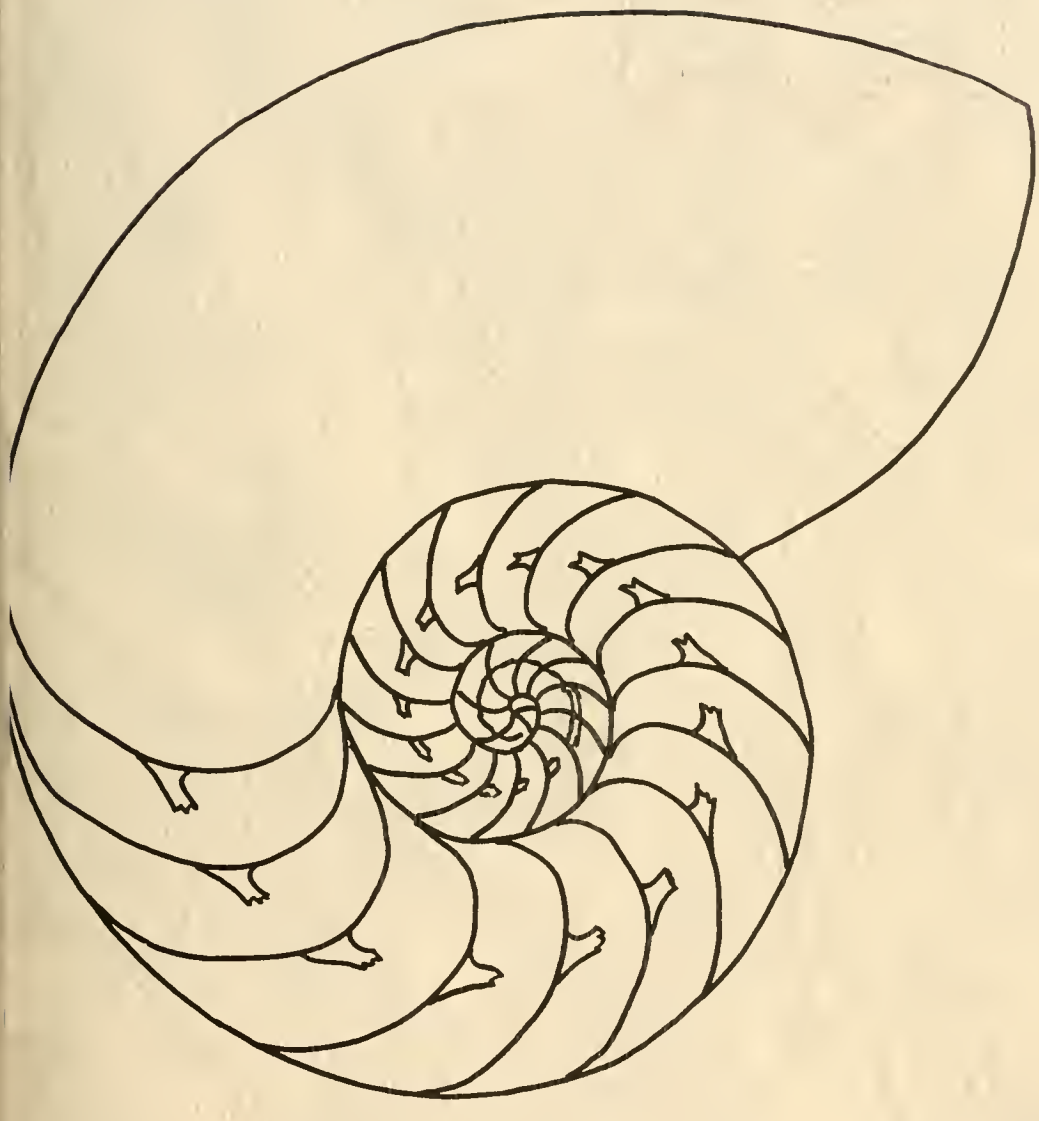

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RECENT DEATHS

Joshua L(ongstreth) Baily, Jr. died on April 18, 1981, in Mission Hills, California, at the age of 92. He was born Jan. 29, 1889, in Philadelphia, PA. He graduated from Haverford College (A.B., 1912; A.M. 1913) and Johns Hopkins (Sc.D., 1938). A Quaker, he served in the American Red Cross in World War I. He was a past-president and charter member of the A.M.U. and later in life moved to California where he was associated with the San Diego Society of Natural History where his collection and library are now housed. A biobibliography appears in *Festivus,* vol. 8, no. 5, p. 63 and in *American Malacologists,* 1st ed., 1973, p. 195.

Ralph H(amilton) Humes died on April 17, 1981, in Leesburg, FL, at the age of 79. He was born Dec. 25, 1902, in Philadelphia, PA. He was a well-known sculptor and an active collector and student of Florida and Cuban tree snails of the genus *Liguus* for many years. His collection was given to the Everglades National Park museum. A short biography appears in *American Malacologists,* 1st ed., p. 312. He is survived by his wife, Janet C. Humes, 2616 Azalea Pt., Leesburg, FL. 32748.

TWO NEW INDO-PACIFIC SPECIES OF *MORUM* (GASTROPODA: TONNACEA)

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ABSTRACT

Morum (Oniscidia) macdonaldi, *n. sp. (type locality Kwajalein Atoll, Marshall Islands) and* M. (O.) joelgreenei, *n. sp. (type locality, Gulf of Davao, Mindanao Island, Philippines) are described. The former taxon represents the first Micronesian record for the genus* Morum *in the western Pacific Ocean. Nineteen living species of* Morum (sensu lato) *are now known (13 in the Indo-Pacific, two in the eastern Pacific, and four in the western Atlantic). Some of these taxa are poorly known and require additional study.*

Although the genus *Morum (sensu lato)* was more widely distributed during the Tertiary with species known from Europe, India, Indonesia, New Zealand, Japan, and the Americas (from Florida to Peru), the surviving members of the subgenera *Oniscidia* and *Herculea* are best represented in the western Pacific Ocean. Here most of the species live in the waters off the Old World continent, ranging from southern Japan, the Ryukyu Archipelago, Taiwan, to the Philippines, and are found in the southwestern Pacific waters in New Guinea, New Caledonia, and eastern Australia. One species *(Morum ponderosum),* however, occurs in the south-central Pacific at Pitcairn Island; it is also recorded from the Ryukyu Archipelago, New Caledonia, and off Queensland, Australia. With the discovery of the new species described herein from the Marshall Islands, the genus is now known from Micronesia. In contrast, the discovery of another new species in the Philippines is not unexpected, as many new and otherwise interesting mollusks have been recently recovered in this archipelago by industrious collectors.

In addition to the two species described below, the following Recent species of *Morum* are known, 1. Indo-Pacific, *M. (Oniscidia): cancellatum* (Sowerby, I, 1824); *exquisitum* (Adams and Reeve, 1848); *grande* (A. Adams, 1855); *macanbrewi* (Sowerby, III, 1889); *praeclarum* Melvill, 1919; *bruuni* Powell, 1958; *teramachii* Kuroda and Habe, *in* Habe, 1961; *uchiyamai* Kuroda and Habe, *in* Habe, 1961; *watsoni* Dance and Emerson, 1967; *kurzi* Petuch, 1979; *M. (Herculea) ponderosum* (Hanley, 1858). 2. Eastern Pacific, *M. (Morum) tuberculosum* (Reeve, 1842); *M. (Oniscidia) veleroae* Emerson, 1968. 3. Western Atlantic, *M. (Morum) oniscus* (Linné, 1767); *M. (Oniscidia): dennisoni* Reeve, 1842); *strombiformis* (Reeve, 1842); *matthewsi* Emerson, 1967.

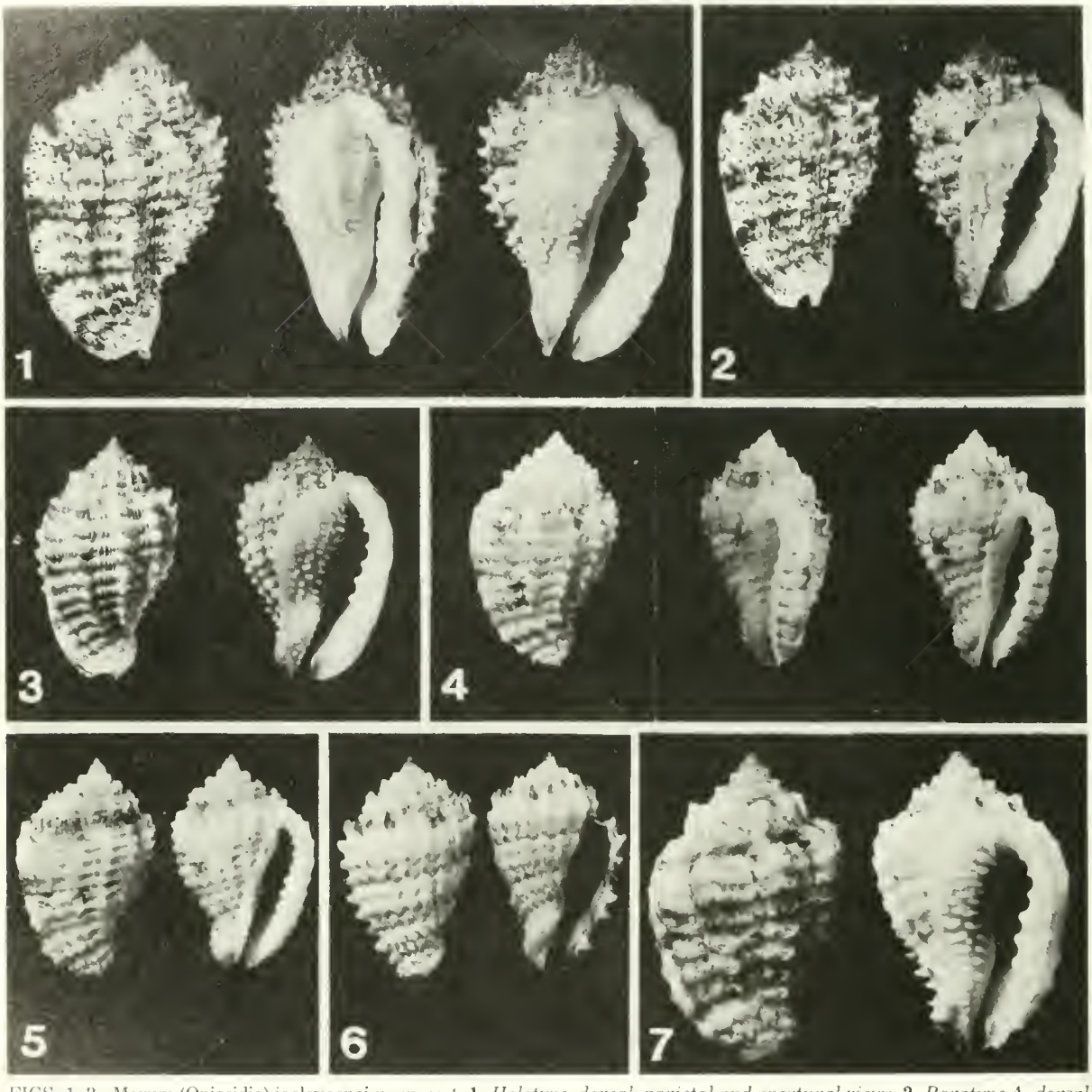
One or two of these nominal species are perhaps best considered a *nomen inquirendum,* until additional specimens can be obtained. A few others require anatomical study in order to determine their biological validity.

Family *Cassidae* Swainson, 1832
Genus *Morum* Röding, 1798

Type species by monotypy: *Morum purpureum* Röding, 1798 [=*Strombus oniscus* Linné, 1767], Recent, western Atlantic. *Morum s.s.* is represented by a few Plio-Pleistocene to Recent, New World species with knobbed, subcylindrical shells.

Subgenus *Oniscidia* Mörch, 1852

Type species by monotypy: *Oniscia cancellata* Sowerby, I, 1824, Recent, Indo-Pacific (See I.C.Z.N. Opinion 1040, 1975). Represented by several Eocene to Recent, largely world-wide species with extended spires and cancellate



FIGS. 1–3. Morum (Oniscidia) joelgreenei *n. sp.* × *1.* **1,** *Holotype, dorsal, parietal and apertural views.* **2,** *Paratype A, dorsal and apertural views.* **3,** *Paratype B, dorsal and apertural views.*
FIGS. 4–6. Morum (Oniscidia) macdonaldi, *n. sp.,* × *2.* **4,** *Holotype, dorsal, parietal, and apertural views.* **5,** *Paratype A, dorsal and apertural views.* **6,** *Paratype B, dorsal and apertural views; note immature apertural characters.*
FIG. 7. Morum (Oniscidia) kurzi *Petuch, 1979.* × *2; Delaware Mus. Nat. Hist. no. 126393; holotype, dorsal and apertural views. All photographs by S. S. Horenstein.*

sculpture of broad axial ribs and narrower spiral cords.

Morum (Oniscidia) joelgreenei,
new species
Figs. 1–3

Description– Shell triangularly ovate, moderately stocky with a wide shoulder, attaining 46+ mm (holotype, fig. 1); spire extended; protoconch of 3½ smooth whorls, erect and papillate; 5+ postnuclear whorls cancellated, with 10 moderately weak spiral cords, crossed by 10 conspicuous, spinose axial ridges (varices) per

whorl; juncture of spiral cords and varices with a sharp, hooked spine; spines most prominent at the shoulder; intervarical areas with 8 to 10 evenly spaced axial lamellae; parietal shield large with outer margin raised and covered with numerous pustules; parietal pustules linear near the aperture, pimplelike on the outer margin; outer lip thickened, crenulated and toothed; 9 primary teeth form linear bifid projections on the inner labial margin, secondary teeth confined to postmarginal surface; anal sulcus shallow; siphonal canal short, recurved, open.

Color—Nucleus shiny, light-tan; postnuclear whorls with whitish base color, overlaid with flecks of reddish brown; 4 widely interrupted brownish spiral bands on body whorl (1 band on shoulder, 2 on either side of midbody area, 1 near the base); darkest coloration of bands on side facing apertural face of each varical spine and on edge of outer lip; bands more defused in Paratype B; parietal shield glazed, buff color with posterior surface tinged a pale lavender-white; pustules white; outer lip glazed, buff color with dark-brown blotches (4 major blotches formed at labial base of spiral bands and 2 secondary blotches between each spiral band).

Material examined—Holotype A.M.N.H. 203719 (fig. 1), 46.4 mm in length, 29.8 mm in width; Paratype A, A.M.N.H. 201362 (fig. 2), 39.4 mm in length, 26.1 mm in width (both *ex*-Joel Greene collection from type locality); Paratype B, (fig. 3), 35.3 mm in length, 22.8 mm in width (William Bledsoe collection, from Panglao, Bohol Island, Philippines, from tangle nets, in 146 meters, June 1980).

Type locality—Davao Gulf, Mindanao Island, Philippines, netted in 200 meters in 1980 by Filipino shell fishmen.

Distribution—Known only from Davao Gulf and Bohol Strait.

Etymology—Named for Joel Greene, an avid collector and a purveyor of shells.

Remarks—This species is reminiscent of the western Atlantic species *Morum (Oniscidia) dennisoni* (Reeve, 1842; Dance and Emerson, 1967, p. 93–94, pl. 12, figs. 5–7), but differs in details of the sculptural ornamentation and in the coloration of the aperture and parietal shield. *Morum (O.) exquisitum* (Adams and Reeve, 1848), a species also known only from Philippine waters (Emerson, 1977, p. 83, 84, figs. E, F, J), has a more robust shell, with stronger and more numerous axial ribs, and a purplish pink parietal shield and outer lip. *Morum (O.) kurzi* Petuch (1979, p. 7, figs. 10–13), recently described from the Philippine Islands, has a smaller shell with coarser sculpture and an orange-colored parietal shield and outer lip (fig. 7). The Sino-Japanese species, *M. (O.) macandrewi* (Sowerby, III, 1889; Habe, 1964, p. 67, pl. 20, fig. 4), has coarser sculpture, stronger banding, with a white parietal shield and a white outer lip bordered with numerous dark blotches on the outer labial rim.

Morum (Oniscidia) macdonaldi, *new species*

Figs. 4–6

Description—Shell somewhat pyriform, broadly shouldered, small for group, attaining 17+ mm in length (holotype, fig. 4); spire weakly extended; protoconch of 3 whorls, erect and papillate; 4+ postnuclear whorls cancellated, with 12 strong spiral cords, crossed by 16 prominent axial ridges (varices); juncture of spiral cords and varices with a blunt, weakly hooked spine, spines most conspicuous at the shoulder; intervarical pits with 6 to 10 weakly raised striae; parietal shield small, largely confined to columella wall, with outer margin raised and covered with numerous small pustules, mostly pimplelike; outer lip narrowly thickened, crenulated and toothed with about 10 major denticles on the inner labial surface; 3 minor denticles near anterior end of siphonal canal; anal sulcus weakly notched; siphonal canal short, gently recurved, open.

Color—Nucleus shiny, pinkish-tan; postnuclear whorls with creamish tan base color, 4 discontinuous purplish-brown bands on body whorl (1 band on shoulder, 2 on either side of midbody area, and 1 near the base; bands less interrupted on paratype with juvenile aperture (fig. 6); darkest coloration of bands on the apertural sides of varical spines and at base of outer lip; parietal shield poorly glazed, with white pustules; labial margin white, not blotched.

Material examined—Holotype A.M.N.H.

203713, 17.3 mm in length, 10.8 mm in width (fig. 4); Paratype A, A.M.N.H. 203714, 16.1 mm in height; 9.5 mm in width (fig. 5); Paratype B, A.M.N.H. 203715, 15.8 mm in length, 10.2 mm in width (fig. 6); Paratype C, A.M.N.H. 203716, 15.9 mm in length, 10.1 mm in width (all *ex*-D. J. MacDonald collection); 2 Paratypes, D. J. MacDonald collection.

Type locality—West reef of Kwajalein Atoll, between the islands of Kwajalein and Ninni, Marshall Islands, in about 15 meters, on sandy rubble under coral boulders, along the ocean side dropoff of the fringing reef (*teste* D. J. MacDonald, February 23, 1981).

Distribution—Known only from the type locality.

Etymology—Named for the collector, D. J. MacDonald. He recognized the uniqueness of this discovery and submitted specimens to Robert W. Morrison, who in turn kindly transmitted the material to me for study.

Remarks—Somewhat resembling a tiny, immature *Morum (O.) macandrewi* (Sowerby, III, 1889), this distinctive species is the first representative of the genus reported from the Marshall Islands. The molluscan fauna of these atolls is well known (*e.g.* Dietrich and Morris, 1953; Brost and Coale, 1971). The difficulties of collecting on the ocean side of the reefs and the diminutive size of the shells undoubtedly have contributed to the failure to find specimens in the past. No specimens were obtained inside the lagoon. Mr. MacDonald reports examining about a dozen specimens, including two living ones discovered at night on patches of sand near coral rubble. None of the six specimens recorded here were live-taken, but several were obtained in a well-preserved condition, as is the case of the holotype and the figured paratypes.

ACKNOWLEDGMENTS

I am indebted to the following collectors for their generosity in submitting specimens for study: William Bledsoe of Los Angeles, California, Joel Greene of San Francisco, California, Robert W. Morrison of Sarasota, Florida, D. J. MacDonald of Kwajalein Atoll, and Carl C. Withrow of St. Petersburg, Florida. Virginia O. Maes and Robert Robertson of the Academy of Natural Sciences of Philadelphia, Russell Jensen of the Delaware Museum of Natural History, and Joseph Rosewater of the U.S. National Museum of Natural History, kindly provided information on material in their respective institutional collections. I thank my colleagues, Sideny S. Horenstein and William E. Old, Jr., for technical assistance.

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AGE RELATIONS AND ZOOGEOGRAPHIC IMPLICATIONS OF LATE PLEISTOCENE MARINE INVERTEBRATE FAUNAS FROM TURTLE BAY, BAJA CALIFORNIA SUR, MEXICO

William K. Emerson[1], **George L. Kennedy**[2], **John F. Wehmiller**[3], and **Everly Keenan**[3]

ABSTRACT

Two Pleistocene marine terraces at Turtle Bay, northwestern Baja California Sur, Mexico (27.7° N. lat.) have been dated at approximately 120,000 and 95,000 years B.P. on the basis of amino-acid racemization in fossil mollusks. These ages imply a correspondence to the early and middle-to-late parts, respectively, of marine oxygen-isotope stage 5. Faunal differences between the upper (24-27 m), 120,000-B.P. terrace and the lower (12 m), 95,000-B.P. terrace conform to the age relations and faunal-temperature aspects documented previously in other localities on the Pacific coast of North America. Faunal assemblages from these terraces contain both extralimital northern and southern species, an enigmatic situation not uncommon in East Pacific Pleistocene deposits. However, nearly 50% of the species from the upper terrace are warm-water (subtropical and tropical) taxa, whereas only 5% are cool-water (warm temperate) taxa. Conversely, the lower terrace fauna is composed of 21% extralimital northern taxa, and only a minor (9%) southern, warm-water element.

INTRODUCTION

Pleistocene marine invertebrate faunules from two marine-terrace deposits at Turtle Bay[4], northwestern Baja California Sur, Mexico (Figs. 1, 2), contain distinct warm- and cool-water elements (Emerson, 1980). These faunal differences, in comparison with similar faunal differences known to represent discordant ages elsewhere (Kern, 1977; Kennedy, 1978; Lajoie *et al.*, 1979), suggest that the warmer and cooler water assemblages at Turtle Bay might also represent different ages. To test this hypothesis, we examined the extent of amino-acid racemization in mollusks from each assemblage, and derived estimates of both relative and absolute ages. We also considered the zoogeographic implications of the temporally distinct assemblages (Emerson, 1980).

Amino-acid racemization methods can serve as both relative and semi-quantitative tools for

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[4]Turtle Bay (27°41'N., 114°52'W.) is also known as Bahía Tortugas, the port of which is Bahía San Bartolomé or Puerto Bartolomé.

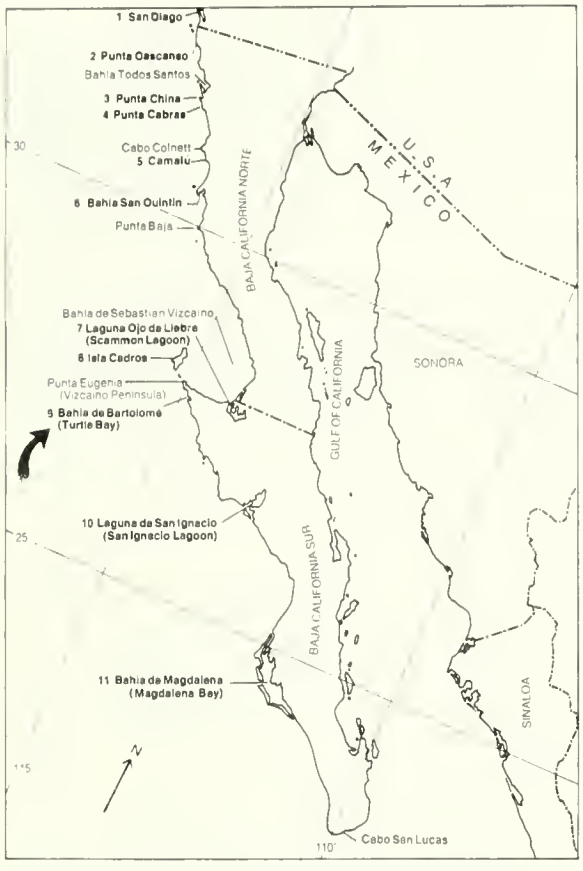

FIG. 1. *Index map of Baja California, Mexico, showing Pleistocene localities (numbered 1 to 11), Turtle Bay (locality 9), and geographic place names representing the modern range endpoints of some components of the Turtle Bay faunas.*

dating Quaternary mollusks (see Hare *et al.*, 1980, for recent review and references). Recent studies of Pleistocene mollusks from both the Atlantic and Pacific coasts of the United States have shown that D/L values increase with age in Pleistocene samples with known stratigraphic relations. In addition, the temperature dependence of amino-acid racemization has been documented with D/L data from three roughly coeval (~120,000-yr.) uranium-series-dated localities over a broad latitudinal range on the Pacific coast (24° N. to 35° N.) (Wehmiller and Emerson, 1980). The ~120,000-yr. amino-acid isochron thus generated allows interpolation of amino-acid enantiomeric ratios (D/L values) at intermediate temperatures, such as for the localities at Turtle Bay.

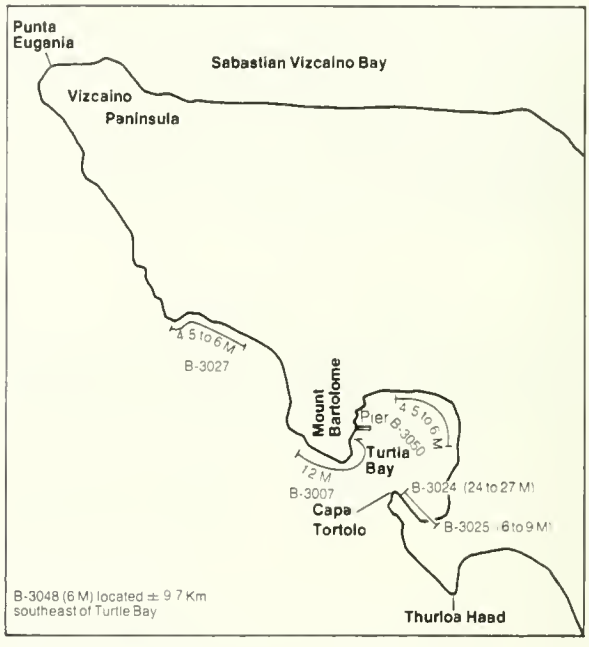

FIG. 2. *Sketch map (not to scale) showing the approximate location of fossiliferous terrace remnants in the Turtle Bay area.*

The fossils used herein are part of a collection made in 1956 by the late E. C. Allison from six localities in the vicinity of Turtle Bay (Fig. 2) (see "Register of Localities" for collection data). These collections are now in the University of California Museum of Paleontology (UCMP), Berkeley. Specimens for amino-acid analysis are from two of these localities, one containing a warm-water assemblage (UCMP loc. B-3024) and the other a cool-water assemblage (UCMP loc. B-3007). Locality B-3024 is on a 24 to 27-m-high terrace along the inner, bay side of Cabo Tortolo, a peninsula forming the southwest margin of Turtle Bay; locality B-3007 is on a 12 m-high terrace along the northwest margin of the bay, round its mouth. Although terrace remnants are present at several elevations around Turtle Bay (Ortlieb, 1979; Emerson, 1980), we herein refer to localities B-3024 and B-3007 as the upper and lower terraces, respectively.

PROCEDURE

We analyzed a total of 13 samples of the venerid bivalve mollusks, *Saxidomus nuttalli* Conrad, 1837, *Chione undatella* (Sowerby,

1835), and *C. californiensis* (Broderip, 1835), to determine the extent of racemization of their component amino acids. Multiple analyses, including repeats of the same shell, were necessary to discriminate the slight differences in age expected between the two localities. Amino-acid analyses were performed according to the procedures of Kvenvolden *et al.* (1972), Frank *et al.* (1977), Wehmiller *et al.* (1977), and Wehmiller and Emerson (1980). Capillary column gas chromatography was performed on either NTFA-isopropyl derivatives or NTFA-(+)-2-butyl derivatives of the total amino-acid mixture. The NTFA-(+)-2-butyl derivatives were analyzed with a Perkin-Elmer Sigma 2 gas chromatograph, using a 100-m glass capillary column coated with OV225, programmed as follows: increase from 115° to 140°C at 1.5°/min, 36 min isothermal; increase at 2°/min to 165°C, 150 min isothermal. Chromatographic conditions for the NTFA-isopropyl derivatives are found in Wehmiller and Emerson (1980). When both procedures were used, sample extracts were split and derivatized after all the hydrolysis and desalting steps. Excellent baseline resolution for at least seven amino acids is possible by the combination of these two procedures. The enantiomeric ratios (D/L) reported herein represent mean values of peak-height ratios from at least two chromatograms.

Table 1 lists the enantiomeric ratios of seven amino acids in the Turtle Bay samples. These data generally satisfy the criterion of reproducibility and are consistent, within typical analytical uncertainty, with relative intergeneric and intrageneric racemization (Lajoie *et al.*, 1980). The only significant deviations occurred in the glutamic acid data for *Saxidomus* from locality B-3007. In these samples, the glutamic acid D/L values were too high in comparison with the ratios of other amino acids, particularly leucine.

Table 1. Amino Acid Enantiomeric (D/L) Ratios From Chione and Saxidomus From Turtle Bay, Baja California Sur, Mexico

(UCMP localities B-3007 and B-3024)

Sample #	Species	Loc.	LEU	GLU	VAL	ALA	PRO	PHE	ASP	%Cal.	Method
79-62-1	C. undatella	B-3007	.57	.53	.50	.83	.64	.70	nd	<.8	B
"			.56	.51	.50	.87	nd	.58	.76	<.8	P
79-62-2			.56	.57	.47	.87	nd	.58	.76	nd	P
79-62-3			.52	.55	.53	.91	nd	.49	.75	nd	P
79-62-4			.53	.55	.53	.91	nd	(.6)	nd	nd	P
79-63-1	S. nuttalli	B-3007	.65	.61	.51	nd	nd	.61	.62	<.8	P
79-63-1R			.62	.58	.49	.97	nd	.65	.59	<.8	P
79-62-2			.64	.63	.53	.94	nd	.65	.69	<.8	P
79-62-2R			.63	.52	.47	.91	nd	.60	.60	<.8	P
79-64-1a	C. californiensis	B-3024	.58	.63	.55	.93	nd	.57	.69	nd	P
79-64-1b			.60	.59	.58	.94	nd	.59	.66	nd	P
79-64-2			.71	.64	.61	.89	.70	.76	nd	<.8	B
"			.69	.62	.59	.94	nd	.59	.70	<.8	P
79-64-2R			.61	.55	.48	1.0	nd	.66	.64	<.8	P
79-64-3			.61	.57	.55	.91	nd	.62	.73	nd	P
"			.63	.57	.56	.86	.72	.70	nd	nd	B
79-65-1	S. nuttalli	B-3024	.73	.62	.51	.92	.84	.75	nd	<.8	B
"			.71	.63	.54	.93	nd	.65	.67	<.8	P
79-65-1R			.69	.58	.51	.99	nd	.66	.58	<.8	P
79-65-2			.64	.59	.45	.86	.78	.74	nd	<.8	B
"			.67	.57	.48	.94	nd	.60	.69	<.8	P
79-65-3			.64	.58	.50	.94	nd	.59	.65	<.8	P

Notes for Table 1:

Amino acid abbreviations:

LEU	Leucine	PRO	Proline
GLU	Glutamic Acid	PHE	Phenylalanine
VAL	Valine	ASP	Aspartic Acid
ALA	Alanine		

%Cal. % Calcite
nd not determined

Methods: B - (+)-2-butyl derivative on OV 225 column.
P - isopropyl derivative on Chirasil Val column.

Samples labelled "R" represent second fragment cut from a shell valve;
Samples split for analysis by two chromatographic methods represent single fragments, the hydrolyzate of which was split after desalting for separate derivatization.
Samples 79-64-1a and 79-64-1b are the two valves of a single articulated specimen of Chione.

DISCUSSION

Enantiomeric ratios for the Turtle Bay samples (Table 1) imply a small but significant difference in age between the two sample localities. Differences in enantiomeric ratios between each locality, however, are slight and fall barely outside the range of normal analytical scatter, especially for the *Saxidomus* data. Although the ratios from each locality overlap slightly, the difference in mean D/L values is 2–5% for *Saxidomus* and 6–10% for *Chione*, depending on which amino acid is compared. According to Miller and Hare (1980), these differences would be significant at the 90–95% confidence level. It might be argued, however, that the amino-acid results do not reflect any age difference, but are instead due to typical analytical scatter (in the case of *Saxidomus*), or species-level effects on racemization kinetics (in the case of *Chione*). Because of our accumulated observations on numerous samples of both species of *Chione* and two species of *Saxidomus* (Lajoie *et al.*, 1980; unpublished data), we believe the best interpretation is of a real age difference.

Figure 3 plots D/L leucine values against local mean annual air temperature for three uranium-series dated localities along the Pacific coast, at Cayucos, San Diego (Nestor Terrace), California, and at Magdalena Bay, as well as D/L leucine values for Bird Rock Terrace at San Diego.

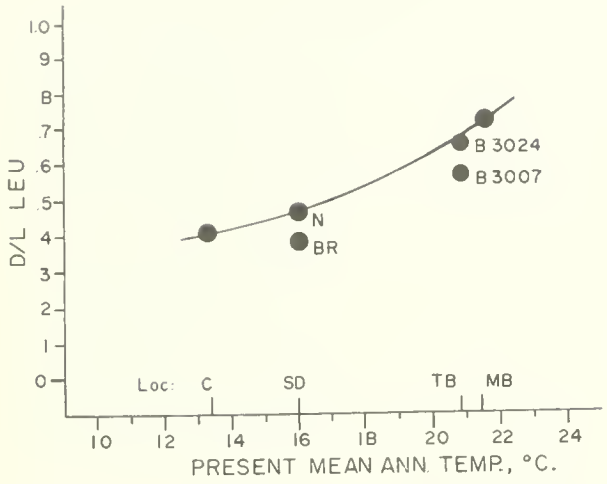

FIG. 3. *Comparison of D/L leucine values from Turtle Bay samples with 120,000-yr. B.P. isochron of D/L leucine vs. present mean annual temperature (after Wehmiller and Emerson, 1980). Calibration localities, connected by solid line, are: Cayucos (C, 35.3°N. lat.); Nestor Terrace (*N, *at San Diego,* SD, *32.7°N. lat.); Magdalena Bay (*MB, *24.6°N. lat.). Data for Bird Rock Terrace (*BR, *at* SD*), which is known to be younger than the Nestor Terrace (Kern, 1977), imply a leucine kinetic model age of 80,000 ± 10,000 years (Wehmiller* et al., *1977). The plotted D/L leucine values for Turtle Bay (*TB*), 0.57 ± 0.03 for loc. B-3007 and 0.65 ± 0.03 for loc. B-3024, are mean values of all data, factored to account for intergeneric differences in* Chione, Protothaca, *and* Saxidomus *(Lajoie* et al., *1980), and for differences produced by the two analytical methods used in this study (Wehmiller and Emerson, 1980:32, footnote). The present mean annual temperature at Turtle Bay is 20.9°C. (Hastings, 1964). The leucine model age for loc. B-3007 is 95,000 ± 15,000 years, using 120,000 years as the "calibration" age for loc. B-3024 and a slightly cooler Effective Quaternary Temperature for B-3007.*

The age of Bird Rock Terrace, which occurs below the 120,000-B.P. Nestor Terrace, is estimated at 80,000 ± 15,000 B.P. by amino-acid dating (Wehmiller *et al.*, 1977) and from its geologic relation to the Nestor Terrace (Kern, 1977). Both the faunal characteristics and relative extent of racemization of the Nestor/Bird Rock Terrace pair resemble those of the upper and lower terraces at Turtle Bay and invite comparison along these lines.

The data points plotted in Figure 3 are mean values of all the D/L leucine determinations in *Chione, Protothaca,* and *Saxidomus* from each locality. These data have been factored slightly to allow comparison of results obtained from different genera[5] and by the two analytical methods mentioned previously (see Wehmiller and Emerson, 1980:32, footnote).

The Turtle Bay data are plotted at a mean annual air temperature of 20.9°C (Hastings, 1964). The data point for the upper terrace (loc. B-3024) lies just below the smooth 120,000-yr. (early stage 5) isochron drawn through the three uranium-series-dated calibration points. The separation between the isochron and locality B-3024 data point is analytically only marginally significant, and can not be considered as reliable evidence for an age significantly less than 120,000 B.P. because of uncertainties in their local Effective Quaternary Temperature histories[6]. For example, if the difference in the assigned temperatures of Magdalena Bay and Turtle Bay was 0.3°C greater than that used herein, the B-3024 data point would lie on the isochron. Small differences in effective-temperature histories create an inherent uncertainty in amino-acid dating, especially in cases where only small increments of time are being resolved.

The data point for the lower terrace (loc. B-3007) plots well below the 120,000-yr. isochron and cannot be considered contemporaneous unless unreasonably large effective-temperature differences are invoked. Assuming an equal effective Quaternary temperature history for both terraces (and an age of 120,000 B.P. for the upper terrace), the age estimate for the lower terrace would be approximately 85,000 ± 15,000 B.P., using the leucine kinetic model of age estimation (Wehmiller *et al.*, 1977). Because localities younger than 120,000 B.P. probably have had a slightly cooler (0.3–0.5°C.) effective-temperature history (Wehmiller *et al.*, 1976; Wehmiller *et al.*, 1977: fig. 16, table 1), the age

[5]*Protothaca* and *Chione* are assumed to have equivalent kinetics; *Saxidomus* data have been converted to "equivalent-*Protothaca*" values (Lajoie *et al.*, 1980).

[6]The Effective Quaternary Temperature (EQT) is the temperature representing the average rate constant, and integrated temperature history, for a fossil sample (see Wehmiller *et al.*, 1977; Kvenvolden *et al.*, 1979; Wehmiller and Emerson, 1980; Wehmiller, 1981).

estimate for the lower terrace is herein revised to approximately 95,000 B.P. (see Wehmiller *et al.*, 1977:68, for discussion of similar temperature modeling of the Bird Rock Terrace age estimate).

In summary, the early and middle-to-late stage 5 amino acid age estimates for the upper and lower terraces at Turtle Bay are based on small differences in analytical results that could also be due to factors other than age. Nevertheless, the simplest, and we believe the best, interpretation is of a real difference in age (within a single interglacial stage) between the two terrace remnants at Turtle Bay (locs. B-3024, B-3007). Implications of an apparent difference in the age and faunal character of the terraces at Turtle Bay and elsewhere along the Pacific Coast (Kern, 1977; Kennedy, 1978) are discussed below.

Faunal comparisons of Turtle Bay assemblages

The upper Pleistocene terrace deposits from Turtle Bay have yielded 138 species of metazoan invertebrates, mostly mollusks (Emerson, 1980). When these fossils were collected, they were believed to represent a single period of deposition. Although most of the terrace deposits around Turtle Bay are horizontal in attitude, some are clearly deformed or faulted (McIntyre and Shelton, 1957; Minch *et al.*, 1976), and the differences in elevation were attributed to this post-depositional deformation. The fossiliferous terrace remnants in the vicinity of Turtle Bay (Fig. 2) actually represent several terrace levels: at 4.5 to 6 m (UCMP locs. B-3027, B-3050, B-3048), at 6 to 9 m (loc. B-3025), at 12 m (loc. B-3007), and at 24 to 27 m (loc. B-3024) (elevations determined by E. C. Allison, see Fig. 2 and Emerson, 1980). However, Ortlieb (1979:Fig. 1) recorded terrace elevations in the Turtle Bay area at 5, 12, 20, and 50 m.

Two of the terrace localities (UCMP loc. B-3024, B-3025) contain warm-water (subtropical and tropical) species and were correlated with marine oxygen-isotope substage 5e (~Sangamon interglaciation) (Emerson, 1980) on the basis of faunal comparisons with other dated assemblages (Kennedy, 1978). Four other assemblages from Turtle Bay (locs. B-3027, B-3050, B-3007, and B-3048) lack these warm-water species and were not assigned to any interglacial or isotopic stage on the basis of their faunal composition (Emerson, 1980).

Emerson (1980) reported 83 positively identified species (53 gastropods, 28 bivalves, 1 chiton, and 1 echinoid) from locality B-3024 and 34 taxa (16 gastropods, 17 bivalves, and 1 echinoid) from locality B-3007 (Tables 2–5). In all, 20 species (12 gastropods and 8 bivalves), about 20% of the total number of taxa, are common to both localities. No extinct species have been recognized in these faunas.

Comparison of the modern geographic ranges of the species from the upper and lower terraces (locs. B-3024 and B-3007, respectively) show basic differences in the zoogeographic composition of each fauna. Combined, the faunas contain 25 tropical (Table 2), 17 subtropical (Table 3), and 8 warm-temperate (Table 4) species. The warm-water fauna of the upper terrace contains 19 gastropods and 5 bivalves that have modern northern endpoints of range south of Turtle Bay (Table 2). An additional 14 species (6 gastropods, 7 bivalves, and 1 chiton) occur only as far north as the Isla Cedros-Bahía de Sebastián Vizcaíno area, and three other species (two gastropods and one bivalve) range only as far north as Bahía de Todos Santos in Baja California Norte (Table 3). Thus, the assemblage from the upper terrace contains distinct tropical and subtropical elements representing nearly one half (49%) of the fauna. On the other hand, the assemblage from the lower terrace contains only three southern species (one gastropod, one bivalve, and one echinoid) that do not occur today as far north as Turtle Bay (Tables 2, 3). The two mollusks are common to both localities.

Table 4 lists warm-temperate species with southern endpoints of range north, or in the vicinity, of Turtle Bay. This northern element is represented by only four species (three gastropods, one bivalve) on the upper terrace and by seven species (two gastropods and five bivalves) from the lower terrace. Of these, two gastropods and one bivalve are common to both localities. The northern species from the upper

Table 2. Southern (tropical) Faunal Elements From Turtle Bay Localities B-3024 and B-3007

[Names in brackets for species not collected at locality B-3024, but recorded from SDSNH 0624 (=locality B-3024; Emerson, 1980].

Species with modern northern endpoints of range that occur south of, or in the vicinity (*) of Turtle Bay.

	Collecting Stations	
Mollusca: Gastropoda	B-3024	B-3007
Bulla punctulata	x	-
Cancellaria cassidiformis	x[1]	-
Cantharus elegans	x[1]	-
Cerithium maculosum	x	-
Columbella major	x	-
Conus fergusoni	x[1]	-
Conus perplexus	x[1]	-
[*Conus purpurascens*]	x	-
[*Cypraea annettae*]	x	-
[*Cypraea arabicula*]	x	-
Hormospira maculosa	x[1]	-
Nerita scabricosta	x	-
Oliva incrassata	x[1]	-
Oliva polpasta forma *davisae*	x[1]	-
Phyllonotus erythrostomus	x	-
Strombus gracilior	x	-
[*Strombus granulatus*]	x	-
Thais biserialis	x[1]	-
Trigonostoma goniostoma	x	-
Bivalvia		
[*Arcopsis solida*]	x	-
Chione picta	x	-
Ostrea angelica	x[1]	-
Semele flavescens	x[1]	-
Trachycardium panamense	x[1]	-
Echinodermata: Echinoidea		
Eucidaris thouarsii	-	x

[1] Species also recorded from SDSNH loc. 0624 (Chace, 1956; Emerson, 1980, table 1).

Table 3. Southern (subtropical) Faunal Elements From Turtle Bay Localities B-3024 and B-3007

[Names in brackets are species not collected at locality B-3024, but recorded from SDSNH 0624 (=locality B-3024, Emerson; 1980].

Species with modern northern endpoints of range occurring on the west coast of Baja California, north of Turtle Bay in the Isla Cedros-Bahía de Sebastián Vizcaíno area, unless otherwise indicated.

	Collecting Stations	
Mollusca: Gastropoda	B-3024	B-3007
Acanthina lugubris[2]	x[1]	-
Anachis coronata forma *hannana*	x	-
Crucibulum scutellatum	x[1]	-
Eupleura muriciformis	x[1]	-
Macron aethiops[3]	x[1]	x
Terebra armillata	x[1]	-
Turbo fluctuosus	x[1]	-
[*Vitularia salebrosa*]	x	-
Bivalvia		
Argopecten circularis s.s.	x[1]	-
[*Barbatia gradata*]	x	-
[*Barbatia reeveana*]	x	-
Chione gnidia	x[1]	-
Dosinia ponderosa	x	-
Megapitaria squalida	x[1]	-
Protothaca grata[4]	x[1]	x
Tellina simulans	x	-
Polyplacophora		
[*Stenoplax magdalenensis*]	x	-

[1] Species also recorded from SDSNH loc. 0624 (Chace, 1956; Emerson, 1980, table 1).

[2] Northern endpoint of range: Bahía Todos Santos.

[3] Northern endpoint of range: 24 km north of Bahía San Quintín.

[4] Northern endpoint of range: Cabo Colnett.

terrace represent less than 5% of the assemblage, in comparison with 21% for the lower terrace assemblage.

The remaining 46 species, all mollusks (Table 5), have modern ranges that overlap the latitude of Turtle Bay. Many of these species terminate their ranges to the north at Point Conception, California (41%), and to the south on the west coast of Baja California Sur (65%).

Amino-acid racemization data are not avail-

Table 4. Northern (warm temperate) Faunal Elements From Turtle Bay localities B-3024 and B-3007

[Names in brackets for species not collected at locality B-3024, but recorded from SDSNH 0624 (=locality B-3024; Emerson, 1980). Same usage in Table 5].

Species with modern southern endpoints of range that occur north of, or in the vicinity (*) of Turtle Bay.

	Collecting Stations	
Mollusca: Gastropoda	B-3024	B-3007
Cypraea spadicea	x	x
**Lottia gigantea*	x[1]	-
**Olivella biplicata*	x[1]	x
Bivalvia		
**Chaceia ovoidea*	-	x
**Glans carpenteri*	-	x
**Milneria minima*	-	x
Saxidomus nuttalli	x	x
**Transennella tantilla*	-	x
[*Crepidula onyx*]	x	-
Crucibulum spinosum	x[1]	-
**Elephantulum carpenteri*	x	-
#Fartulum occidentale	x	x
#Fissurella volcano	x	x
**#Haliotis fulgens*	x	-
[*Hipponix antiquatus*]	x	-
#Hipponix tumens	x	-
**#Nassarius tegula*	x[1]	-
**Neverita reclusiana*	x[1]	-
**#Norrisia norrisi*	-	x
**#Pseudomelatoma penicillata*	x	-
**#Pteropurpura festiva*	x[1]	x
**#Serpulorbis squamigerus*	-	x
**#[Tegula aureotincta]*	x	x
**#Tegula eiseni*	x	x
**#Tegula gallina*	x[1]	x
#Trivia solandri	x	-
**#Truncatella californica*	x[1]	-

[1]Species also recorded from SDSNH loc. 0624 (Chace, 1956; Emerson, 1980, table 1).

Table 5. Other Species (non-extralimital) From Turtle Bay Localities B-3024 and B-3007

Species with modern northern and southern endpoints of range occurring north and south, respectively, of Turtle Bay. Species with northern endpoints of range extending no farther north than Point Conception, California indicated by an asterisk (*); species with southern endpoints of range terminating on the west coast of Baja California Sur indicated by a number sign (#).

	Collecting Stations	
Mollusca: Gastropoda	B-3024	B-3007
#Alia carinata	x	x
**#Astraea undosa*	x[1]	x
[*Bursa californica*]	x[1]	-
#Caecum crebricinctum	-	x
#Caecum dalli	x	x
#Collisella limatula	x	-
#Conus californicus	x[1]	x
Bivalvia		
**#Amiantis callosa*	x	-
Anomia peruviana	x	x
**Chione californiensis*	x	x
#Corbula luteola	x	x
**Crassinella pacifica*	x	-
Cryptomya californica	x	x
[*Diplodonta orbellus*]	x	x
**#Donax californicus*	x	-
#Epilucina californica	-	x
Felaniella sericata	x	-
#Hinnites giganteus	-	x
**#Leporimetis obesa*	x[1]	x
Lucinisca nuttallii	x[1]	-
#Macoma indentata	x	-
#Macoma nasuta	-	x
Parvilucina approximata	-	x
[*Penitella fitchi*]	x	-
#Penitella penita	-	x
**#Semele decisa*	x	-
Tagelus californianus	x	-

[1]Species also recorded from SDSNH loc. 0624 (Chace, 1956; Emerson, 1980, table1).

able for most of the Turtle Bay assemblages, and so any temporal correlations must be made on the basis of faunal or geomorphic evidence. E. C. Allison, who collected these fossils, believed loc. B-3025 to be on a tilted remnant of the 24 to 27 m terrace represented at loc. B-3024. Locality B-3025 was previously referred (Emerson, 1980) to isotopic substage 5e, owing to the presence of four extralimital tropical and subtropical mollusks in its fauna (*Conus regularis*, *Oliva polpasta* forma *davisae*, *Thais biserialis*, and *Ostrea angelica*). The remaining six taxa in the small fauna all have modern geographic ranges that overlap the latitude of Turtle Bay. The presence of an extralimital southern element and the geologic setting suggest that localities B-3024 and B-3025 are probably coeval and referable to the warm-water phase of the Sangamon Interglaciation (Emerson, 1980).

Assemblages from the remaining Turtle Bay localities – B-3027 (northwest of the bay on the outer coast), B-3050 (inner northeastern margin of the bay), and B-3048 (southeast of the bay on the outer coast) (see Fig. 2) – are dominated by species still living in the region, but include both extralimital northern and southern taxa. Extralimital southern species present at these localities are *Thais biserialis*, *Trachycardium panamense*, and *Protothaca grata*, each of which occurs in loc. B-3024, and the latter two in loc. B-3007. Three northern extralimital species also occur in loc. B-3050 (*Lottia gigantea*, *Saxidomus nuttalli*, and *Tresus nuttallii*), two of which are present in loc. B-3024. Because of the small size of these other faunas and the presence of both extralimital northern and southern species, we hesitate to assign precise ages to them at this time. Further amino-acid racemization determinations on elements of these faunas would probably resolve the question of their ages.

In summary, it is difficult to imagine that faunas (from locs. B-3024 and B-3007) with such striking differences in their zoogeographic composition could have been deposited contemporaneously, and the amino-acid data presented herein support their temporal difference. Although both assemblages contain both extralimital northern and southern species, indicative of a shift in the geographic ranges of a few component species subsequent to deposition, the overall faunal composition of each assemblage reflects different hydroclimatic conditions. Thus, nearly half (49%) of the assemblage from the upper terrace is made up of warm-water (subtropical and tropical) faunal elements, in comparison with only 9% of these elements on the lower terrace. In contrast, 21% of the taxa from the lower terrace are northern, cool-water (warm temperate) species, in comparison with only 5% of the taxa from the upper terrace (Tables 2–4).

Comparison with other faunas from Baja California Sur

Late Pleistocene megainvertebrate faunas from the west coast of Baja California Sur have been reported from only three areas in addition to Turtle Bay (lat. 27°41′N.) (Fig. 1): (1) Laguna Ojo de Liebre (Scammon Lagoon, lat. 27°57′N.) – 24 molluscan species from "raised beaches near Scammon's Lagoon" (Jordan, 1924); (2) Laguna de San Ignacio (San Ignacio Lagoon, lat. 26°45′N.) – 88 species of mollusks (Hertlein, 1934; including taxa cited previously by Jordan, 1924); and (3) Bahía de Magdalena (Magdalena Bay, lat. 24°30′N.) – 442 species-group taxa, mostly mollusks (Jordan, 1936; incorporating previous records of Dall, 1918, Smith 1919, and Jordan, 1924). The Magdalena Bay fauna is the largest Pleistocene fauna described from anywhere in Baja California.

No amino-acid or radiometric dates are available for the faunas at Scammon Lagoon or San Ignacio Lagoon. However, at Magdalena Bay, uranium-series dates on both corals and echinoids indicate an average age of 116,500 ± 6,000 B.P. for Magdalena Terrace (Omura *et al.*, 1979). These radiometric dates suggest that Magdalena Terrace is correlative with a high-stand of sea level at approximately 125,000 to 120,000 B.P., equivalent to the early, warm-water phase of the last interglacial stage (substage 5e) of the marine oxygen-isotope record (Shackleton and Opdyke, 1973). The uranium-series date on the Magdalena Terrace has been used subsequently by Wehmiller and Emerson (1980) to calibrate the southern temperature

range of the 120,000-yr. isochron shown in Fig. 3.

Amino-acid racemization data suggest that the fauna from the upper terrace at Turtle Bay (loc. B-3024) and that from Magdalena Bay (CAS loc. 754 of Jordan [1936] = loc. F-6 of Omura *et al.* [1979]) probably were deposited contemporaneously. Faunal comparison (Table 6) of these two assemblages suggests a slightly warmer hydroclimate at Magdalena Bay, not totally unexpected because of its more southerly location (Fig. 1). Both the absolute number and the percentage of tropical and subtropical taxa are greater at Magdalena Bay than at Turtle Bay, although both sites supported similar faunas rich in these elements. Conversely, the number of warm-temperate (*i.e.*, extralimital northern) taxa at Turtle Bay is greater than at Magdalena Bay.

Comparison of the fauna from the lower terrace at Turtle Bay (loc. B-3007) with the noncontemporaneous fauna at Magdalena Bay shows greater discrepancies (Table 6). Thus, although three-fourths of the non-extralimital species at Turtle Bay also occur at Magdalena Bay, only three of the seven warm-temperate taxa occur there. Moreover, two of the three tropical and subtropical species are common to both localities.

Table 6. Comparison of Positively Identified Species in Turtle Bay Faunas with Those of the Magdalena Bay Faunas.

	(A)		Present at CAS loc. 754 and loc. F-6		Present at Magdalena Bay (cf. Jordan, 1936)	
	#	= %	#	% of (A)	#	% of (A)
Loc. B-3024						
Total Species	83	= 100%	63	76%	74	89%
Tropical	24	29	21	87%	23	96%
Subtropical	17	20%	13	76%	15	88%
Non-extralimital	38	46%	28	73%	33	86%
Warm temperate	4	5%	1	25%	3	75%
Loc. B-3007						
Total species	34	= 100%	15	44%	23	68%
Tropical & subtropical	3	9%	1	33%	2	66%
Non-extralimital	24	70%	13	54%	18	75%
Warm temperate	7	21%	1	14%	3	43%

Comparison with more northern localities

The temporal and faunal relations of the upper and lower terraces at Turtle Bay invite comparison with other terrace pairs on the Pacific coast. The best known of these pairs is at Point Loma in San Diego, California, where Nestor and Bird Rock Terraces occur in superposition. The upper terrace (Nestor) has been dated by uranium-series methods on corals at 121,000 ± 10,000 B.P. (Ku and Kern, 1974), and the lower terrace (Bird Rock) by amino-acid methods (Wehmiller *et al.*, 1977) and geologic evidence (Kern, 1977) at approximately 80,000 B.P. Thus, the terraces at Point Loma can be correlated to the early and late phases of marine oxygen-isotope stage 5 and correspond to the ages obtained herein for the terrace pair at Turtle Bay.

Although it is inappropriate to make a direct species comparison of the San Diego and Turtle Bay faunas because of the distance separating them (~600 km) and of the different depositional settings, their zoogeographic relationship can be examined. The fauna of Nestor Terrace contains both extralimital northern and southern species, but is dominated by southern species; this observation suggests seasonal temperatures warmer than those now prevailing in the San Diego area (Kern, 1977). The fauna of lower and younger Bird Rock Terrace contains few (4%) extralimital northern elements, but lacks extralimital southern species; this observation suggests marine temperatures lower than those of the San Diego area (Kern, 1977).

The similarity of the radiometric and amino-acid age estimates for these widely separated terrace pairs (southern California and northern Baja California Sur), as well as their similar zoogeographic compositions, is strong evidence that near-shore marine waters were successively warmer and cooler than those of today during the early and middle-to-late parts, respectively, of marine oxygen-isotope stage 5 (130,000–80,000 B.P.).

Provincial assignments of Turtle Bay assemblages

The original usage of a single provincial

designation for a geographically prescribed area (Valentine, 1961; Addicott, 1966) must now be tempered by the recognition of more than one marine-terrace level (and associated fauna) at elevations previously believed to represent contemporaneous deposition (Kennedy, 1978, 1979). In the San Diego, California area, for example, assemblages from late Pleistocene terrace deposits that previously were considered coeval are now referable, on the basis of radiometric and amino-acid age estimates, to three temporally distinct episodes of deposition (Ku and Kern, 1974; Kern, 1977; Masters and Bada, 1977; Wehmiller *et al.*, 1977; Lajoie *et al.*, 1979; Deméré, 1980; and Karrow and Bada, 1980). The recognition of several possible terrace ages that relate to highstands of sea level during different glacial minima requires that provincial faunas be identified by their respective ages (Kennedy, 1978). Establishment of a geochronology that is related to the deep-sea isotopic chronology of glacial minima and maxima (Shackleton and Opdyke, 1973) facilitates the assignment of an isotopic-stage number to the modern or Pleistocene provincial name most representative of that fauna (Kennedy, 1978).

Valentine (1961:393) proposed the Magdalenan Province for late Pleistocene molluscan assemblages characterized by tropical and subtropical faunas at Magdalena Bay and elsewhere along the coast of Baja California Sur, the Gulf of California, and the adjacent mainland of Mexico. The Magdalenan Province is here restricted to faunal assemblages that are referable to the 130,000- ~120,000-B.P. highstand of the sea, correlative with the early part of marine oxygen-isotope stage 5 (substage 5e). The warm-water assemblages at Turtle Bay (loc. B-3024 and probably loc. B-3025) are herein assigned to the Magdalenan Province. Other warm-water faunas from along the southern Baja California coast at San Ignacio Lagoon (Hertlein, 1934) and at Scammon Lagoon (Jordan, 1924) probably also can be assigned to the Magdalenan Province. However, provincial assignments based entirely on faunal inferences should be tempered by some means of absolute dating, especially if their faunas are small and contain a mixture of northern and southern species.

The cooler water, middle-to-late stage 5 assemblage at Turtle Bay (loc. B-3007) is not as readily assigned a Pleistocene provincial designation because the more northerly Verdean and Cayucan Provinces also have been restricted to early stage 5 faunas (Valentine, 1980). Until more of the known localities along the Baja California coast are dated, either biochemically or radiometrically, and can be shown to represent either early or late stage 5 time, provincial delineation will remain difficult. Fossil localities with faunas that still need provincial assignment include those at Cedros Island (Hertlein, 1934), and in Baja California Norte at San Quintín (Jordan, 1926), Punta Cabras (Addicott and Emerson, 1959), Punta China (Emerson, 1956), and Punta Descanso (Valentine, 1957). A fauna at Camalú has been assigned already to the Pleistocene Verdean Province by Valentine (1980).

Register of Localities

University of California Museum of Paleontology, Berkeley, California. All fossils were collected by E. C. Allison. For locality data of Magdalena Bay localities, see Omura *et al.*, (1979).

UCMP loc. **B-3007.** Terrace deposit at an elevation of about 12 m, N. 30°E. of peak on south side of entrance to Turtle Bay. Collected June 18, 1956.

UCMP loc. **B-3024.** Terrace, traceable for several hundred meters, at an elevation of 24 to 27 m, along the southwestern part of Turtle Bay in back and south of small fishing camp. Collected June 26, 1956.

UCMP loc. **B-3025.** Terrace at an elevation of 6 to 9 m southeast of loc. B-3024 and possibly equivalent to the terrace at loc. B-3024, because it appears to be tilted in that direction. Collected June 26, 1956.

UCMP loc. **B-3027.** Terrace at an elevation of 4.5 to 6 m immediately behind long sandy beach along southwestern part of peninsula northwest of Turtle Bay. Collected June 27, 1956.

UCMP loc. **B-3048.** Terrace at an elevation of approximately 6 m that extends along the open coast adjacent to a long sand-gravel beach about

9.7 km southeast of Turtle Bay. Collected July 2, 1956.

UCMP loc. **B-3050.** Terrace at an elevation of 4.5 to 6 m along the northeast side of Turtle Bay. Collected July 3, 1956.

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CATINELLA VAGANS (PILSBRY) AND A NEW SPECIES OF *CATINELLA* (SUCCINEIDAE PULMONATA) FROM THE SHORE OF LAKE WACCAMAW, NORTH CAROLINA

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ABSTRACT

Pilsbry (1948), on the bases of differences of shell features as well as of the reproductive systems, recognized two "varieties" of Catinella (Quickella) vagans. *The type locality of* C. vagans *is Cape May Point, New Jersey; locality of the second "variety" is Lake Waccamaw, North Carolina. The observations of Pilsbry* (ibid), *as well as my own, are sufficient reasons for recognizing these two populations as distinct species of* Catinella.

In 1900 Pilsbry described *Succinea campestris vagans* from Cape May Point, New Jersey; this species is now known as *Catinella vagans* (Pilsbry). Later Pilsbry mentioned and figured (1948, p. 844, Fig. 456C) a specimen from the shores of Lake Waccamaw, North Carolina,

which varied in certain details from the type series. The observations of Pilsbry (1948:843–845) as well as my own are sufficient reasons for recognizing these two populations as distinct species.

Shell characteristics, patterns of pigmentation of body and mantle, structural details of radulae and jaws, and the anatomy of reproductive systems are criteria for identification of genera and species of Succineidae. Geographic distribution, geographic barriers, microhabitats, adaptation to environmental conditions, time of maturing and mating seasons also are significant factors to be considered in the recognition of species, especially in the family Succineidae.

Catinella vagans (Pilsbry)

Succinea campestris vagans Pilsbry, 1900. *The Nautilus*, 14(7):74.

Quickella vagans (Pilsbry) 1948. *Land Mollusca of North America*, vol. 2, Pt. 2:843–845; Figs. 443d, 456A, B, C.

Because of beach erosion, the type locality on Cape May Point, New Jersey, as known at the time Pilsbry described *Succinea campestris vagans* no longer exists. On June 7, 1979, I obtained a number of *Catinella vagans* from two localities in the vicinity of what is now known as Cape May Point, New Jersey, namely: (1) D. S. Franzen Field No. 494, shore of pond, city of Wildwood pumping station, on New Jersey Highway 47, northwest of Rio Grande, Cape May County, New Jersey. A colony of *C. vagans* was living under fine litter on the wet, flat shore of the pond. Some *C. vagans* were crawling on grass blades. The edge of the pond supported growths of predominately willow *(Salix)* and poison ivy *(Rhus)*. (2) D. S. Franzen Field No. 495, Cape May County Park located between U.S. Highway 9 and the Garden State Parkway Lake Shore Road, city of Cape May Court House, Cape May County, New Jersey. Several *C. vagans* were on the wet, sandy loam soil of a small bay of the shore of the freshwater lake. Trees growing along the shore included willow *(Salix)*, sweet gum *(Liquidamber)*, maple *(Acer)* and oak *(Quercus)*. A third locality: D. S. Franzen Field No. 499, June 13, 1979. Burton's Pond located on south edge of Angola, Route Delaware 24E, Sussex County, Delaware. Only two *C. vagans* were found living on twig litter on the wet bank of the pond. The small number might be attributed to the last spring's flooding of the flood plain. The bank supported growths of willow *(Salix)* and bulrush *(Scirpus)*. *Typha* and *Saggitaria* grew at the edge and in shallow water of the pond.

The following is a description of *Catinella vagans* as now known from the vicinity of Cape May Point, New Jersey:

Shell–(Fig. 1A, B) Shell globose-ovate, amber-colored, translucent, fragile, imperforate, composed of 2–1/4 to 3 inflated, sharply incised whorls; height 7.6 mm to 10.8 mm; width 5.0 mm to 6.4 mm (Table 1); nuclear whorl appressed, spire short; whorls increase rapidly resulting in a tumid ultimate whorl. Ovate aperture occupies seven tenths to eight tenths of height of shell (Table 1). Surface of nuclear whorl finely granular, sometimes mottled whitish because of worn periostracum; striations fine on penultimate whorl, gradually becoming moderately coarse towards the aperture; sharply edged peristome fragile; callus on ultimate whorl may not be visible. Amber-colored columella follows inner border of peristome curving as it ascends into the ultimate whorl.

Head, Body and Mantle Surfaces–"The cream-white body and head are sparsely peppered with minute dots" (Pilsbry, 1948, p. 845). The series of *Catinella vagans* from the three

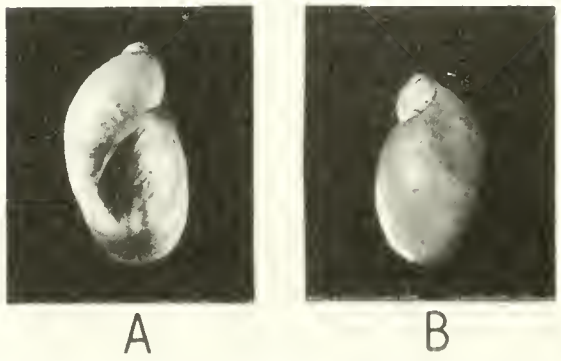

FIG. 1. **A**, Catinella vagans *(Pilsbry) (Height 10.5 mm).* **B**, Catinella vagans *(Pilsbry) (Height 9.5 mm). Both shells from D. S. Franzen Field No. 494: Pond, city of Wildwood pumping station, Cape May County, New Jersey.*

	No. of Whorls	Height	Width	Width/ Height	Height of Aperture	Width of Aperture	H. Ap./ H. Shell	W. Ap./ W. Shell	W. Ap./ H. Ap.
Field #494	2 3/4	10.8 mm	6.4 mm	.592	8.4 mm	5.1 mm	.777	.796	.607
Pumping Station, City of Wildwood, Cape May County, New Jersey	3	10.7	6.4	.598	8.2	4.8	.766	.750	.585
	3	10.5	6.0	.571	7.8	4.1	.742	.733	.564
	2 3/4	9.8	6.0	.612	7.4	4.5	.755	.750	.607
	3	9.8	5.8	.591	7.2	4.6	.734	.793	.638
Range (16 shells)	2 1/4-3	7.6-10.8	5.0-6.4	.567-.663	5.8-8.4	3.8-5.1	.726-.797	.730-.851	.564-.677
Median		9.5	5.7	.619	7.2	4.4	.766	.76	.626
Field #495	3	10.6 mm	6.7 mm	.632	8.2 mm	5.0 mm	.773	.746	.609
Cape May County Park, Cape May Court House, Cape May County, New Jersey	2 2/3	9.5	6.0	.631	7.0	4.5	.736	.75	.642
	3	9.3	5.7	.612	6.7	4.0	.720	.701	.597
	3	9.0	6.0	.666	7.0	4.2	.777	.70	.60
	2 1/4	8.2	4.8	.585	6.6	3.7	.804	.770	.560
Range (8 shells)	2 1/4-3	6.1-10.6	4.1-6.7	.585-.679	5.0-8.2	3.0-5.0	.720-.819	.70-.777	.560-.672
Median		9.0	5.7	.632	6.7	4.1	.777	.75	.609
Field #499	2 3/4	10.1 mm	6.1 mm	.603	7.4 mm	4.5 mm	.732	.737	.608
Burton's Pond, Angola, Sussex County, New Jersey	2 1/3	9.1	5.0	.549	6.8	4.0	.747	.80	.588

TABLE 1. *Dimensions of shells of* Catinella vagans *(Pilsbry). The measurements are of the five largest shells of the first two localities and of the two shells obtained from the third locality. In the 4th column of measurements are listed the ratios of the width of the shell over its height. In the last 3 columns are listed the ratios of height of aperture over height of shell, width of aperture over width of shell, width of aperture over height of aperture.*

localities included in this study exhibit variations in pigmentation from those of Pilsbry's description. The following is a description of a representative pigmented *C. vagans* (Field No. D. S. Franzen 494). Surface of head light cream-colored, irregularly tuberculate. Pigmentation of dorsal surface of head consists of a median band flanked on either side by two bands, convergent at anterior end of the head, spreading and then converging at level of base of the superior (posterior) tentacles, spreading again to extend over the remainder of the head region; some bands extend a short distance onto the dorsal, white body surface; on either side of these bands another band extends from the anterior end of the head, over the superior tentacles to continue over the remainder of the head region.

Lateral body wall cream-colored, coarsely and irregularly tuberculate. On either side a broad, pigmented band, consisting of a series of dorsoventral bands, extends from the labial palyp to posterior tip of body. The semi-lunar genital aperture, about 1.0 mm in length, surrounded by a white lip, is situated on right-hand side of body immediately posterior to the head region. On either side a pedal groove, extending from labial palyp to posterior end of body, separates foot from lateral body wall; pedal groove is paralleled by a less pronounced suprapedal groove. Shallow vertical grooves incise suprapedal and pedal grooves and pigmented band, produce scallops along margin of foot especially when animal is in a somewhat contracted state. Sole of foot is cream-colored, unpigmented.

Anterior and posterior inner margin of mantle collar outlined by bands of fine flecks. Free edge of mantle collar, white. Pigmented band along anterior dorsal margin of mantle flecked from left side to mid-dorsal area, becoming solid black on right hand side and terminating as a band of flecks. Across dorsal surface of mantle dark streaks extend from anterior band to area of the cream-colored nephridium where a black band outlines its anterior margin. Posterior to nephridium are scattered patches of pigment. Color of liver is golden brown.

Variations—Color of head varies from almost white to a dark cream. Patterns of pigmentation of head, body and mantle collar are constant, varying only in intensity. Band paralleling mantle collar ranges from very narrow to one which

includes a broad, dark blotch. Pigmentation of mantle assumes various patterns: (1) Narrow streaks of pigment extend over the mantle to anterior margin of nephridium; posterior margin of nephridium outlined by an irregular, broad band. (2) Mantle pigment is in form of a network of streaks becoming broader and more blotched over the nephridium. (3) Very narrow band parallels mantle collar from which broad, netted bands extend for one-third the distance from mantle edge to anterior margin of nephridium; several heavy blotches located in intervening space; anterior margin of nephridium partially outlined by a narrow, lightly pigmented band. "The mantle over the lung is translucent whitish with some faint gray spots (seen under magnification to be composed of minute flecks of pigment); several next to the thickened edge being larger and longer . . . The thick mantle edge . . . not dotted" (Pilsbry, 1948, p. 845).

FIG. 2. *Reproductive organs of* Catinella vagans *(Pilsbry). P, penis; EP, epiphallus; PRM, penial retractor muscle; PA, penial appendage; SP, spermatheca; HD, hermaphroditic duct; AG, albumin gland; GA, genital atrium; VA, vagina; SPD, spermathecal duct; OD, oviduct; PG, prostate gland; SD, sperm duct; OD, oviduct; FS, fertilization sac; SV, seminal vesicle.*

Reproductive System–(Fig. 2) Albumin gland (AG) somewhat larger than prostate gland, triangular in form, composed of fine acini, is enclosed within a thin, transparent, unpigmented sheath. Seminal vesicle (SV) composed of a long lobe and of a shorter, narrower lobe closely adherent to the longer lobe, is enclosed within a thin, sparsely flecked sheath. The lightly to moderately pigmented hermaphroditic duct (HD) joins the seminal vesicle to form the fertilization sac (FS) from which diverge the oviduct (OD) and the sperm duct (SD); the latter leads into the prostate gland. The oval prostate (PG) enclosed by a thin, transparent, unpigmented to sparsely flecked sheath, is composed of acini slightly coarser than those of the albumin gland. The vas deferens follows the penis (P) along its dorsal surface; as it approaches the distal end of the penis it enlarges to form the epiphallus (EP) which enters the unsheathed penis terminally; the penis enlarges immediately into a cylindrical form. The cylindrical penial appendage (PA), approximately the length of the penis, arises from the proximal end of the penis. Fibers of the broad retractor muscle (PRM) attach to the epiphallus, penis and penial appendage. Pilsbry (1948, p. 845) states the penial appendage "is free from the retractor muscle." His Fig. 456A shows a few fibers attached to the penial appendage. The duct (SPD) of the globular spermatheca (SP) is short and stout, sometimes dilated as it approaches the vagina (VA); the vagina is short.

Radula and Jaw–Radulae of three individuals of *Catinella vagans* examined have 91, 96, 97 rows of teeth, respectively. There are few tenth on the anterior-most rows; the number increases rapidly posteriorly. The number of marginals and laterals of representative rows of a radula are recorded in Table 2. Although there is an individual variation of the radulae and, also, of the rows of teeth of a radula, the ratio of marginals to laterals approximates 1:1.

The characteristics of the teeth of *C. vagans* are described as follows and illustrated in Fig. 3, A. The central tooth (C) bears a long, broad, basal plate with a posterior serrated margin flanked on either side by a rounded boss. The pointed mesocone, variable in length, extends downward as far as to the lower third of the basal plate. A short, pointed ectocone flanks the mesocone on either side. The laterals (R-L-1; R-L-10) have a pointed mesocone varying in

TABLE 2. *Formulae of representative of teeth of* Catinella vagans *(Pilsbry).*

Station	Slide	No. of Rows of Teeth	Row	M	L	C	L	M
Field No. 494 Pumping Station, City of Wildwood, Cape May County, New Jersey	A	91	25	11	13	1	13	14
			39	12	15	1	15	12
			62	13	15	1	15	12
			70	13	14	1	14	13

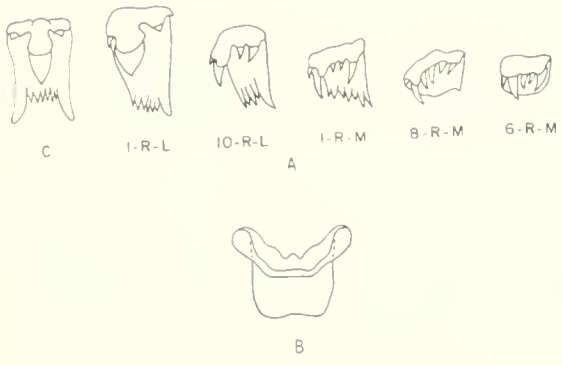

FIG. 3. A, *Representative radula teeth of* Catinella vagans *(Pilsbry). Row 76:* C, *central tooth; 1-R-L, first left lateral; 10-R-L, tenth right lateral; 1-R-M, first right marginal; 8-R-M, eighth right marginal. Row 71: 6-R-M, sixth right marginal.* B, *A jaw of* Catinella vagans *(Pilsbry).*

length from a very short structure to some extending downward to the level of the posterior margin of the basal plate. A small, pointed endocone is present. The ectocone, undivided in the more medial teeth, is divided into two cusps in the more lateral teeth. The distinction between laterals and marginals is not always clear because sometimes a tooth whose ectocone is divided into three cusps is flanked on either side by one whose ectocone is divided into two cusps. The marginals (1-R-M; 8-R-M) smaller than the laterals, have a basal plate which is broader than long, true especially of the outermost marginals. The small endocone is sharply pointed; the pointed mesocone extends to and below the margin of the basal plate. The ectocone is divided generally into three, sometimes into two or four cusps of varying lengths.

The features of the teeth of *C. vagans* compare with those of species of the genus, namely (1) the ratio of the laterals to the marginals approximates 1:1 and (2) the basal plate of the marginals is broader than long. Such features of the genus were noted by Quick to be true of *Catinella (Succinea) arenaria* ("B.-Ch.") (Quick, 1933, Fig. 4, p. 296) and by Franzen of *Catinella parallela* Franzen (Franzen, 1979, p. 66, Table 2; p. 67, Fig. 3A).

The amber-colored jaw is illustrated in Fig. 3B. Anteriorly the collar has a median fold flanked on either side by a larger fold. Posteriorly the margin of the collar has a fold on either side of the median indentation.

Catinella waccamawensis n. sp.

Quickella vagans (Pilsbry) 1948. Vol. II, Pt. 2, pp. 844–845, Fig. 456C.

Description of Holotype–Shell: Fig. 4, A, B. Shell light amber-colored, glossy, translucent, thin, very fragile, imperforate, elongate-ovate, composed of three tumid whorls; suture sharply incised; height 7.1 mm, width 4.6 mm, height of aperture 4.9 mm, width of aperture 3.3 mm. Height of ovate aperture equals 69% of total height of shell (Table 3). Sharply edged peristome very fragile; light amber columella follows inner border of peristome, curves as it ascends into the ultimate whorl. Nuclear whorl knoblike; spire short; whorls increase rapidly in size resulting in an elongate, tumid ultimate whorl. Nuclear whorl finely granular; longitudinal striations fine on penultimate whorl, increasing gradually towards the aperture. Surface coated with fine grains of sand and soil.

Holotype–Catalogue No. FMNH 200983; Paratype No. FMNH 200984 Molluscan Collection, Field Museum of Natural History, Chicago, Illinois. Additional paratypes in the private collection of the author.

Description of paratypes–Shell: (Fig. 4, C, D). Shells of mature snails, attaining a height of 7.5

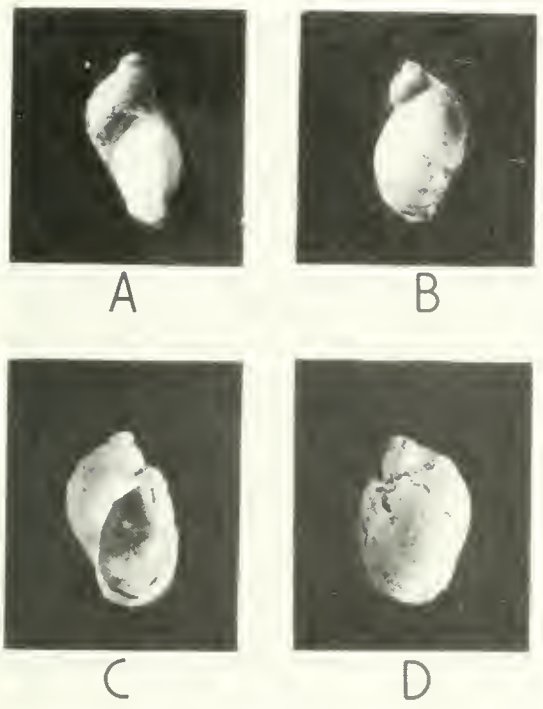

FIG. 4. **A, B,** *Holotype of* Catinella waccamawensis *n. sp. (Height 7.1 mm).* **C, D,** *Paratype of* Catinella waccamawensis *n. sp. (Height 6.5 mm). Type locality, Lake Waccamaw, Columbus County, North Carolina.*

mm, are comprised of 2–1/2 to 3 inflated whorls. Dimensions of the holotype and six paratypes, the median of the series, are recorded in Table 3. The height of the largest shell is 7.5 mm, its width is 5.9 mm. The aperture occupies from 65.5 to 75.0 percent of entire height of shell. Other ratios are to be noted in Table 3. The shells are extremely fragile, break readily, making accurate measurements difficult.

Head, Body and Mantle Surfaces—Surface of head and body wall cream-colored, lightly pigmented, finely, irregularly tuberculate. Pigmentation of dorsal surface of head consists of bands of fine flecks anteriorly forming a triangle, narrowing between the superior (posterior) tentacles into a single band; pigmentation posterior to tentacles diffused over the dorsal body surface; the triangle flanked on either side by a band. Surface of both pairs of tentacles flecked. Retractor muscles of superior tentacles black. Lateral body wall lightly pigmented with fine flecks forming an indistinct band.

Genital aperture, situated on anterior right-hand side of body, lunate, about 0.5 mm in length, surrounded by a white lip. On either side a pedal groove, continuous from labial palyp to posterior lip, separates foot from lateral body wall; pedal groove paralleled by less pronounced suprapedal groove. Shallow, vertical grooves incise pedal and suprapedal grooves, the lateral body wall and the pigmented band, produce shallow scallops along margin of the foot especially when animal is in a somewhat contracted state. Sole of foot is light cream-colored and unpigmented.

Mantle collar is lightly flecked overall. On the mantle a narrow, finely-flecked band parallels the mantle collar from which bands extend to anterior margin of the nephridium. Nephridium white, partially outlined by a narrow, dark band and covered by flecks of pigment. The liver is light golden brown in color. Pigmentation of other paratypes is variable in intensity and distinctness in pattern.

TABLE 3. *Dimensions of shells of* Catinella waccamawensis *n. sp. The measurements are of the seven measureable shells obtained from the type locality. In the 4th column of measurements are listed the ratios of the width of the shell over its height. In the last 3 columns are listed the ratios of height of aperture over height of shell, width of aperture over width of shell, width of aperture over height of aperture.*

	No. of Whorls	Height	Width	Width/ Height	Height of Aperture	Width of Aperture	H. Ap./ H. Shell	W. Ap./ W. Shell	W. Ap./ H. Ap.
Holotype:	3	7.1 mm	4.6 mm	.647	4.9 mm	3.3 mm	.69	.717	.673
Paratypes:	3	7.5	5.9	.786	5.2	3.7	.69	.627	.711
	3	7.3	5.0	.684	5.5	3.8	.75	.76	.69
Type Locality	2 3/4	7.0	4.6	.657	4.8	3.4	.685	.739	.708
Field #483	2 1/2	6.1	3.8	.62	4.0	2.5	.655	.657	.625
Lake Waccamaw	2 3/4	6.0	3.5	.58	4.3	2.7	.71	.77	.627
Columbus County	2 1/2	5.9	3.5	.59	4.1	2.8	.69	.80	.625
North Carolina									
Range (7 shells)	2 1/2-3	5.9-7.5	3.5-5.9	.58-.68	4.0-5.5	2.5-3.8	.655-.75	.627-.80	.625-.71
Median		7.0	4.6	.647	4.8	3.3	.69	.739	.673

Reproductive System–(Fig. 5) The albumin gland (AG) triangular in form, composed of fine acini, enclosed within a thin, transparent, unpigmented sheath; seminal vesicle (SV) enclosed within a thin, transparent, lightly flecked sheath, elongate, bilobed, one lobe small and closely adherent to the larger lobe. The lightly pigmented hermaphroditic duct (HD) and the seminal vesicle join to form the fertilization sac (FS) from which a duct divides into the oviduct (OD) and the sperm duct (SD) which leads into the prostate gland (PG). The oval prostate gland, enclosed by a thin, transparent unpigmented sheath, is composed of fine acini slightly larger than those of the albumin gland (AG).

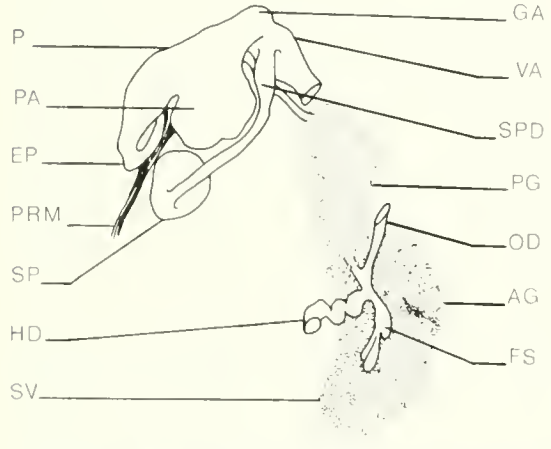

FIG. 5. *Reproductive organs of* Catinella waccamawensis *n. sp. P, penis; PA, penial appendage; EP, epiphallus; PRM, penial retractor muscle; SP, spermatheca; HD, hermaphroditic duct; SV, seminal vesicle; GA, genital atrium; VA, vagina; SPD, spermathecal duct; PG, prostate gland; OD, oviduct; AG, albumin gland; FS, fertilization sac.*

Length of albumin gland exceeds that of the prostate gland. As the vas deferens approaches the penis it follows the penis along its dorsal surface, enlarges to form the epiphallus (EP) to enter the distal end of the unsheathed penis which enlarges immediately into a cylindrical form (P). The penial appendage (PA) whose base is almost half the length of the penis, originates subterminally near where the penis joins the genital atrium (GA); appendage expands into a large pouch-like structure; anterior-posterior dimension of the appendage is almost thrice the diameter of the penis. Fibers of the broad, stout penial retractor muscle (PRM) insert mainly onto the base of the penial appendage; lesser fibers insert onto the penis and onto the epiphallus. The globular spermatheca (SP) is connected to the vagina (VA) by a stout, short spermathecal duct (SPD). The short vagina (VA) expands as it opens into the genital atrium (GA).

Radula and Jaw–Radulae of two paratypes of *Catinella waccamawensis* n. sp. were stained and mounted; the number of rows of teeth, 72 and 73. There are few teeth on the anteriormost rows; the number increases rapidly posteriorly. The number of marginals and laterals are recorded in Table 4. Although there is an individual variation of the radulae and, also, of the rows of teeth of a radula, the ratio of marginals to laterals approximates 1:1. The characteristics of the teeth are described below and illustrated in Fig. 6A.

The central tooth (C) bears a long, broad, basal plate with a posterior serrated margin flanked on either side by a prominent, rounded boss. The pointed mesocone extends downward

TABLE 4. *Formulae of representative rows of teeth of* Catinella waccamawensis *n. sp.*

Station	Slide	No. of Rows of Teeth	Row	M	L	C	L	M
Type Locality: Lake Waccamaw, Columbus County North Carolina	A	73	15	9	9	1	9	8
			29	10	8	1	8	10
			41	10	8	1	9	8
	B	72	31	10	8	1	8	10
			42	10	9	1	9	10
			44	11	8	1	9	10

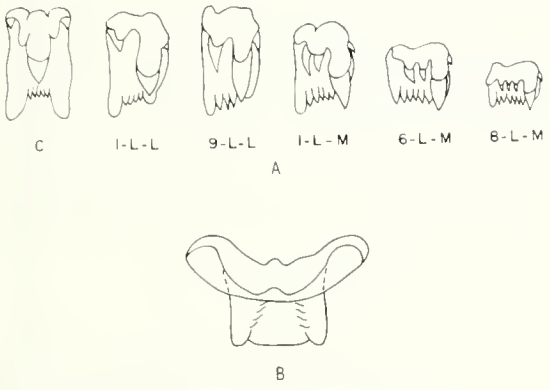

FIG. 6. **A,** *Representative radula teeth of* Catinella waccamawensis *n. sp. Row 45: C, central tooth; 1-L-L, 1st left lateral; 9-L-L, 9th left lateral; 1-L-M, 1st left marginal; 6-L-M, 6th left marginal; 8-L-M, 8th left marginal.* **B,** *A jaw of* Catinella waccamawensis *n. sp.*

to about the lower fourth of the basal plate. A short, pointed ectocone flanks the mesocone on either side. The laterals have a large, long, pointed mesocone flanked medially by a short endocone, laterally by a single ectocone: 1-L-L, 9-L-L. The basal plate of the outermost laterals is shorter than of the more medial laterals. The marginals, smaller than the laterals, have a basal plate broader than long; this is especially true of the outermost marginals. The small endocone is pointed; the larger, pointed mesocone extends beyond the basal plate. The ectocone of the innermost marginals is divided into two, of the outermost into three cusps; 6-L-M, 8-L-M. Features of the teeth of *C. waccamawensis* n. sp. compare with those of species of the genus, namely, the ratio of the laterals to marginals approximates 1:1 and the basal plate of the marginals is broader than long. This is true, also, of *C. vagans* (Pilsbry) as noted above.

The amber-colored jaw is illustrated in Fig. 6B. Anteriorly the collar has a median, bluntly pointed fold flanked on either side by a lower, rounded fold. The posterior margin of the collar is indented medially.

Type Locality - Habitat—Lake Waccamaw, Columbus County, North Carolina, North shore

Comparison of Catinella waccamawensis n. sp. with Catinella vagans (Pilsbry)

Structure	C. waccamawensis n. sp.	C. vagans (Pilsbry)
Shell.		
No. of whorls	2½ - 3	2½ - 3
Height, range	5.9 mm - 7.5 mm	7.6 mm - 10.8 mm
Width, range	3.5 mm - 5.9 mm	5.0 mm - 6.4 mm
H. of shell/W. of shell (Median	.69	.76
Nuclear whorl	knoblike	appressed
Pigmentation of body:		
General	lighter than C. vagans	moderately
Head	pattern not as distinct	distinct bands
Dorsal body wall	diffuse	in form of bands
Lateral body wall	lightly pigmented, indistinct bands	broad band
Mantle	anterior band, narrow	anterior band, variable
	nephridium partially outlined by a narrow band	anterior margin of nephridium outlined by a dark band
Nephridium	white	light cream
Liver	golden	golden brown
Reproductive system		
Penial appendage	pouch-like, anterior-posterior dimension about 3X diamter of penis	cylindrical, approximately length of penis

of Lake Waccamaw at intersection of Lake Shore Drive and McRae Lane (3.7 mi. from junction of U.S. Highway 74 and 76, east end, with Route 214). Date of collection, July 15, 1978. The shore is flat for about twenty feet from shore line to the abruptly rising bank; area shaded by pine *(Pinus)*, willow *(Salix)*, birch *(Betula)* and cypress *(Taxodium)* trees. *Catinella waccamawensis* n. sp. was found living on wet, sandy ground, moist boards and dead leaves along the shore of the lake.

Distinctive Features–Shell: Comprised of 2–1/2 to 3 inflated, sharply incised whorls; maximum height of shells of this series, 7.5 mm, width, 5.9 mm. The median of the height of aperture over height of shell, .69 (69%). Nuclear whorl knoblike, surface finely granular.

Pigmentation–Pigmentation of animal is generally very light. The bands of pigment on the head form a characteristic triangle, a single band courses between the superior tentacles; pigmentation on dorsal body wall is diffuse, not in distinct bands. Pigmentation of lateral body wall is not in form of distinct bands. Pigmentation of edge of mantle varies from a narrow band to absence of a recognizable band. Nephridium is white, not distinctly outlined with a black band. Liver is a golden color.

Reproductive System–Penial appendage is a large pouch-like structure whose base is almost half the length of the penis. Penis is cylindrical in form. Seminal vesicle is bilobed, one lobe small and closely adherent to the larger lobe.

Comparison of the features of *Catinella waccamawensis* n. sp. with those of *Catinella vagans* (Pilsbry) are shown in the outline on previous page.

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National Science Foundation Grants-in-Aid No's. NSF G18000 and NSF GB2715 provided laboratory equipment. Dr. A. Byron Leonard read the manuscript and offered helpful suggestions. Sue Hobbs, Phil Dietz and R. S. Prezant assisted me in the collection of *Catinella vagans* from the various localities.

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THE MORPHOLOGY AND DISTRIBUTION OF *OCENEBRA GRIPPI* (MURICIDAE: OCENEBRINAE)

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ABSTRACT

Ocenebra grippi *(Dall, 1911) ranges from Monterey, California, to Punta Banda, Baja California Norte, Mexico. The radula is illustrated for the first time, and features of the shell morphology and ontogeny are clarified.*

Recent collections by scuba diving have yielded specimens that give information about the radular and shell morphology and range of an obscure muricid species.

References and Synonymy–*Eupleura grippi* Dall, 1911: 87. Dall, 1921: 100; pl. 5, fig. 1.

Oldroyd, 1927: 28; pl. 32, fig. 6. Abbott, 1974: 188; fig. 1964. *Ocenebra grippi* (Dall). Radwin & D'Attilio, 1976: 121; pl. 20, fig. 2.

Material Examined–1) 1 specimen, dead, tidepool, La Bufadora, Baja California Norte, Mexico. *Leg.* G. Radwin, 26 February 1972. (SDNHM 61784)

2) 2 specimens, 60 feet, Ocean Beach, California. *Leg.* C. Snell, May, 1965. (SDNHM 23584)

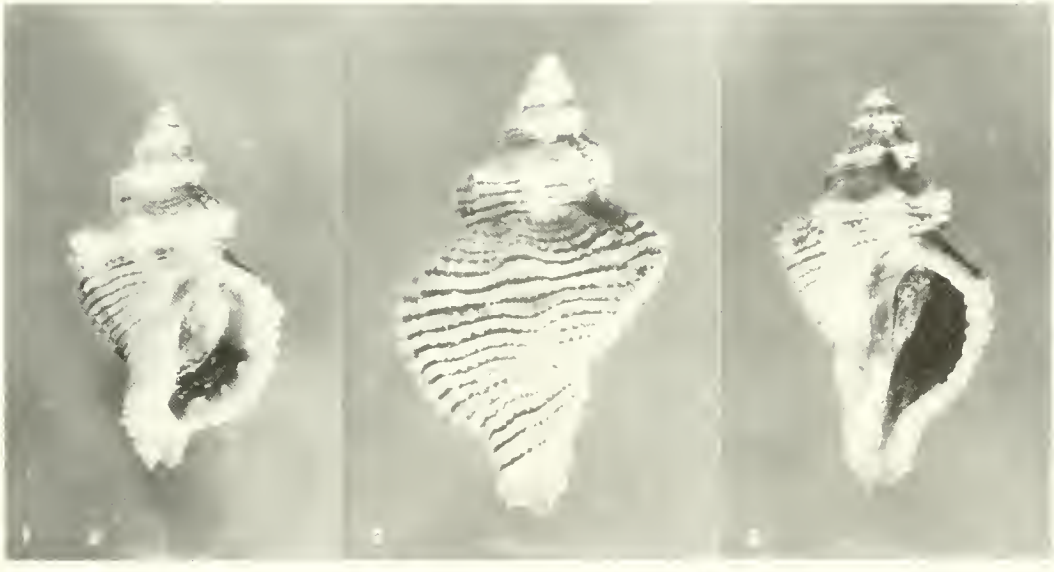
3) 2 specimens, 55 feet, Pt. Conception, California. *Leg.* C. Snell, July, 1966. (SDNHM 55806)

4) 3 specimens, 30 feet, Monterey Bay, California. *Leg.* D. Myers, October, 1978. (2 specimens SDNHM 73668)

Radular Morphology–William Healey Dall described a single, old and worn muricid shell as *Eupleura grippi* by which name the species had been known for years. Radwin and D'Attilio (1976) reassigned *E. grippi* to the genus *Ocenebra* based on shell morphology. Investigation of the radula further substantiates this generic placement (Fig. 4). *Eupleura* has a longer central cusp than *Ocenebra*. The axes of the three major middle cusps of *Eupleura* appear to radiate distally, whereas in *Ocenebra* these axes are nearly parallel. This is the first published illustration of the radula of *O. grippi*.

Shell Morphology, Variability and *Ontogeny*–On the basis of the single holotype specimen, the variability and shell sculpture of the species could not be adequately described. Dall's specimen had only obscure varices and worn nodes at the shoulder. The spiral sculpture was nearly obsolete. The apertural lip was abnormally thickened, had eight denticles and the canal was open.

The diverse characters of this uncommon species were elaborated by Radwin and D'Attilio (1976): five to six rounded axial ribs; nodes at the periphery may be well-developed (Fig. 1); spiral sculpture is of scabrous cords separated by sharply cut grooves (Figs. 2 and 5a); color ranges from brown to yellow with some specimens banded at the shoulder (Fig. 1). The canal is often in varying degrees of closure (Figs. 1, 3 and 5b), an ontogenetic characteristic of the Ocenebrinae (D'Attilio, 1978). The protoconch is distinctive, consisting of one and a quarter nuclear whorls (Fig. 5c). The Monterey



FIGS. 1–3. 1, Ocenebra grippi *(Dall, 1911). Ventral view showing nodes at periphery, denticles and closed siphonal canal. 15 mm × 9 mm. Monterey specimen.* 2, O. grippi *(Dall, 1911). Dorsal view showing scabrous cords. 17 mm × 10 mm. Monterey specimen.* 3, O. grippi *(Dall, 1911). Ventral view showing open siphonal canal. 18 mm × 10 mm. Monterey specimen.*

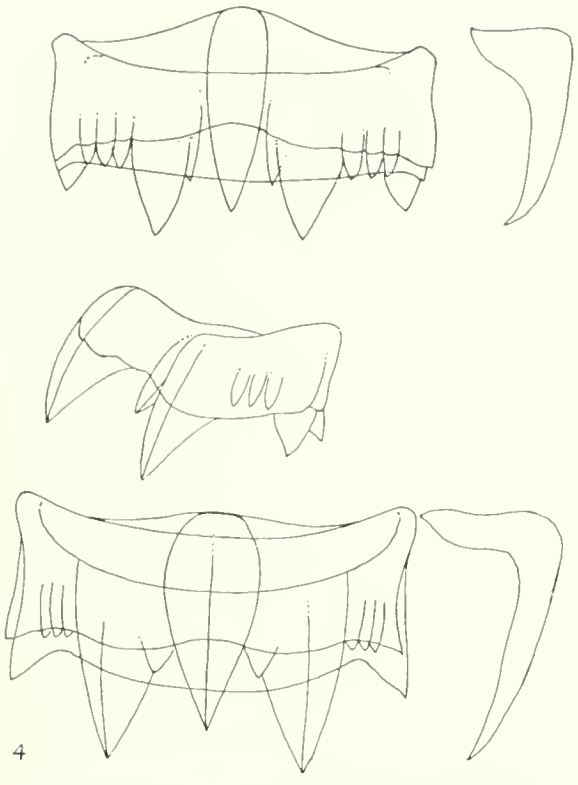


FIG. 4. *Radular dentition of* Ocenebra grippi *(Dall, 1911), collected at Ocean Beach, California. Greatly enlarged; drawing by Anthony D'Attilio.*

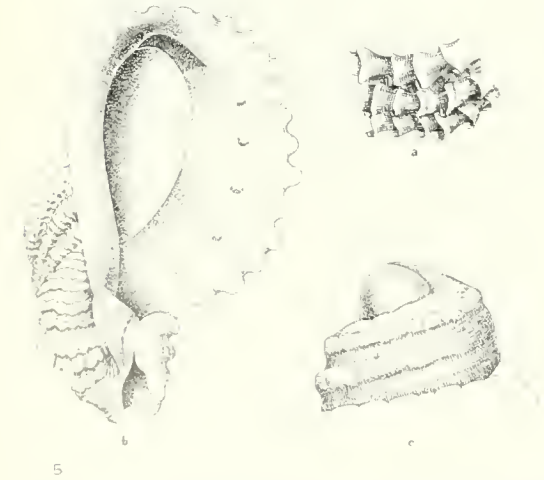


FIG. 5. O. grippi *(Dall, 1911).* **a,** *Detail of spiral sculpture.* **b,** *Detail of apertural lip showing crenulation, denticles and closed siphonal canal.* **c,** *Detail of protoconch. Drawings by Anthony D'Attilio.*

specimens showed further variation, having only five denticles instead of six to ten as stated by Radwin and D'Attilio (1976) and the apertural lip margin is crenulate (Figs. 1 and 5b).

The illustration of the holotype (Dall, 1921) was reproduced in Oldroyd (1927) and the same figure appears in Abbott (1974). This figure does not show any apparent spiral sculpture. The photograph in Radwin and D'Attilio (1976: pl. 20, fig. 2) is unfortunately rather dark and does not show the spiral sculpture.

Range–The type locality for this species is San Diego, California, dredged at 90 feet. The northernmost reported range for *O. grippi* has been Point Conception, California (Radwin and D'Attilio, 1976: 121). Three specimens of this species were collected by David Myers in October, 1978, in Monterey Bay, California in 30 feet of water. This Monterey Bay finding extends the range from Southern California approximately 200 miles into the Oregonian Faunal Province as defined by McLean (1978). Further the bathymetric range now extends from 90 to 30 feet. In addition one beachworn specimen has been found intertidally at Punta Banda, Baja California Norte, Mexico, 60 miles south of its previously known southern occurrence. Further collecting along the Baja California coast of Mexico is needed to clarify the significance of the Punta Banda specimen.

ACKNOWLEDGMENTS

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THE MARINE FAUNAL ZONES OF NORTH CAROLINA, WITH NEW MOLLUSCAN RECORDS

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ABSTRACT

Northern range extensions of Charonia variegata *and* Cooperella atlantica *into North Carolina marine waters are reported for the first time. The occurrence in these waters of* Anomalocardia auberiana, Astraea phoebia, Lima scabra, Pinctada imbricata *and* Spondylus americanus, *previously based on few specimens, is further substantiated. Faunal zones are redefined in relationship to the North Carolina marine molluscan fauna.*

The purpose of paper is to clarify and substantiate several North Carolina range records in the molluscan literature which are based on few specimens; to add several new North Carolina range records; and to discuss the relationship of these records to a reevaluation of faunal zones within North Carolina waters, an area where Cape Hatteras is considered a significant boundary.

All records were collected within the past 14 years and unless specified, are based on adult specimens. Records catalogued in the University of North Carolina, Institute of Marine Sciences Mollusk Collection are indicated by a UNC-IMS number, an asterisk (*) designating live-taken specimens.

Anomalocardia auberiana (Orbigny, 1842). Published range: South half of Florida to Texas (Abbott, 1974). Dall (1902) records the northern range of *A. brasiliana* Gmelin as Wilmington, NC. Subsequent use of North Carolina as the northern range of this species, as recorded in Porter (1974), is likely based on former account. Narchi (1972) states that the North Carolina record of *A. brasiliana*, in error, is for *A. cuneimeris* Conrad, a synonym of *A. auberiana* (Orbigny), (see Abbott, 1974). DATA: Live specimen washed up on Bogue Banks beach, Carteret County (34°41.4′N; 76°47.6′W).

Astraea phoebia Röding, 1798. Published range: Southeast and northwest Florida to Brazil (Abbott, 1974). Menzies, et al. (1966) list the species in their North Carolina report but give no locality data. Later North Carolina range references (Porter, 1974) are probably based on the Menzies et al. report. See also Porter (1974) and Schwartz and Porter (1977) for recent North Carolina records of the species. DATA (11 specimens south of Cape Lookout-Beaufort Inlet area): Juvenile, UNC-IMS#4174 (34°17.5′N; 76°10.8′W; 46 m depth); UNC-IMS #3381 (34°16.5′N; 76°42.0′W; 91 m depth);

UNC-IMS#4035.1–4035.2* (34°20.0′N; 76°42.0′W; 24 m depth); juvenile, UNC/IMS #4036 (34°23.0′N; 76°39.0′W; 24 m depth); UNC-IMS#6145* (34°15.6′N; 76°35.5′W; 32 m depth); UNC-IMS#6343* (South of Cape Lookout; 23–30 m depth); UNC-IMS#7105.1–7105.4 (34°21.8′N; 76°35.0′W; 20–26 m depth). Specimens were found at 20–91 m depth generally in rocky or shelly substrate.

North Carolina is also the northern range of a related species *A. tecta americana* (Gmelin, 1791) [see Porter, 1974; record based on one specimen from south of Beaufort Inlet - UNC-IMS#4039* (34°23.0′N; 76°39.0′W; 33 m depth)].

Charonia variegata (Lamarck, 1816). Published range: Southeast Florida to Brazil (Abbott, 1974); however, Merrill and Petit (1969) record a fresh juvenile fragment off Cape Romain, SC. A Scheltema (1971) larvae record off the North Carolina coast (unlisted by Scheltema but indicated in Figure 6) is listed by Porter (1974). DATA (Seven specimens from south to southeast of Cape Lookout, NC): juvenile, UNC-IMS#4366 (34°9.9′N; 76°10.6′W; 35 m depth); Ross specimen* (34°23.5′N; 76°35.0′W; 24 m depth); Dixon specimen (34°14.0′N; 76°35.0′W; 26–32 m depth); Safrit specimen (34°11.0′N; 76°31.0′W; 31 m depth); UNC-IMS#7106, 7107, and 7131 (34°21.8′N; 76°35.0′W; 20–26 m depth). Specimens were found at 20–35 m depth frequently in rocky or shelly substrate. No shell or living specimens were noted in 1978 by the junior author during dives on "Ten Fathom Rock" (34°21.8′N; 76°35.0′W) but a living specimen was collected in June 1978, on "210 Rock" (34°14.0′N; 76°35.0′W) during a dive organized by Dr. R. Searls; no later records have been reported.

Cooperella atlantica Rehder, 1943. NEW RANGE RECORD. Published range: Southeast Florida to Brazil (Abbott, 1974). DATA (10 specimens from southeast of Cape Lookout to southeast of New River Inlet, NC): UNC-IMS (34°10.0′N; 77°04.0′W; 27 m depth); four specimens (three living), UNC-IMS#5386 (34°12.9′N; 76°13.2′W; 37 m depth); UNC-IMS#6374 (34°11.8′N; 76°36.2′W; 37 m depth); two specimens, UNC-IMS#6463* (34°12.1′N; 76°35.7′W; 37 m depth); UNC-IMS#3832 (33°55.9′N; 76°31.9′W; 35 m depth); UNC-IMS* (34°17.0′N; 76°46.0′W; 20–26 m depth). This species in North Carolina waters may be restricted to depths between 20 and 37 m, the latitude restriction, 33°55.9′ to 34°17.0′, related (?) to a lack of samples at above mentioned depth, north and south of these latitudes.

Lima scabra (Born, 1778). Published range: South Carolina to Brazil (Abbott, 1974), though Emerson and Jacobson (1976) list North Carolina to West Indies. Records near Cape Lookout, NC date back to Stimpson (1860) and Coues (1871); later records, probably based on the aforementioned, are listed in Porter (1974). Jacot (1921) implies, probably correctly, that the Stimpson and Coues records are *Lima inflata* Lamarck (synonym of *L. pellucida* C. B. Adams), a species known living in the Beaufort Inlet and Cape Lookout area. DATA (four specimens from south of Cape Lookout to southeast of Cape Fear, NC): UNC-IMS#2704 (33°28.5′N; 77°27.5′W; 26 m depth); UNC-IMS#6104*, 7132.1*, and 7132.2* (34°14.0′N; 76°35.0′W; 26–32 m depth). Living specimens were attached to under surface of rocks. Many living specimens were seen attached under rocks on "210 Rock" June, 1978–1980 (personal communication – S. Ross) and by junior author.

Pinctada imbricata Röding, 1798. Published range: South Carolina to Brazil (Abbott, 1974); however, Jacot (1921) found a recent-living specimen in the vicinity of Beaufort, NC. Other authors (Porter, 1974), listing North Carolina within the range for this species, are suspected to have as their source data the Jacot report. DATA (two specimens from Cape Lookout Bight and Pine Knoll Shores Beach, NC): UNC-IMS#7870* (34°37.5′N; 76°33.3′W; beach); Howland and Giles specimen* (34°41.7′N; 76°52.2′W; beach). The Howland and Giles specimen was attached to *Sargassum* sp. seaweed. Specimens collected by Jacot and more recently by Ryan (UNC-IMS#7870) may also have been brought into North Carolina waters by *Sargassum* or other drifting objects upon which they may have set. During winter months it is believed that *P. imbricata* might be found

on any beach in North Carolina wherever *Sargassum* is washed ashore.

Spondylus americanus Hermann, 1781. Published range: North Carolina to Brazil (Abbott, 1974); Porter (1974) lists previous North Carolina records and UNC-IMS holdings. DATA (15 specimens from southeast of Cape Lookout to east-southeast of Cape Fear, NC): UNC-IMS#4415* (34°18.5'N; 76°10.8'W; 46 m depth); four specimens (three recent), UNC-IMS#3400 (33°52.0'N; 76°32.0'W; 57 m depth); UNC-IMS#4417 (33°26.0'N; 77°00.9'W; 76 m depth); UNC-IMS#2596* (34°08.1'N; 76°11.4'W; 67–72 m depth); UNC-IMS#4537* (34°09.4'N; 76°08.0'W; 70–119 m depth); two specimens, UNC-IMS#5007 (34°09.6'N; 76°10.1'W; 46–57 m depth); Safrit specimen* and UNC-IMS#7130 (34°21.8'N; 76°35.0'W; 21 m depth); UNC-IMS#7108.1*–7108.3 (34°11.0'N; 76°31.0'W; 31 m depth). Specimens were found in North Carolina waters between 21 and 119 m depth. Recent living specimens have been noted on nearshore North Carolina shipwrecks (pers. comm.–D. Noe). COMMENTS: Molluscan species occurring within the shallow marine waters of North Carolina have been considered members of either the Virginian (Boreal subprovince), Carolinian, and/or the Caribbean Faunal Provinces (Abbott, 1968). Cape Hatteras is usually considered to be the southern boundary of the Virginian and northern boundary of the Carolinian and Caribbean faunas. Faunal overlapping is common. Basically, these faunal provinces or regions are acceptable when considering most groups of marine organisms (Briggs, 1974). The North Carolina marine faunas fall into the following redefined provinces:

Boreal: species having reproducing populations from Labrador south to North Carolina.

Virginian: species having reproducing populations north and south of North Carolina waters. This group may correspond to the "Temperate" or "Virginian" group of Bousfield (1960), defined as ranging from the Gulf of St. Lawrence to northern Florida and the Gulf of Mexico.

Carolinian: species having reproducing populations from Florida north to North Carolina. (Abbott, 1968, and Briggs 1974). In North Carolina waters, the Carolinian species may be restricted to estuarine and nearshore waters of less than 20 or 25 m depth; further north, the species live at depths from 26–156 m (Merrill et al. 1978).

Caribbean: species seldom found north of North Carolina and probably not capable of reproducing within North Carolina waters. Major populations occur offshore in deep water habitats influenced by the warm Gulf Stream (Abbott 1968 and Briggs 1974).

Anomalocardia auberiana, Astraea tecta americana and *Charonia variegata* are members of the Caribbean Province and not capable of sustaining North Carolina populations. As such, they are considered as accidental strays within the North Carolina fauna.

Astraea phoebia, Cooperella atlantica, Lima scabra and *Spondylus americanus* are believed to be members of the Carolinian Province. *Cooperella atlantica* is widely distributed in sandy habitats within the area sampled and have occurred there for several years. *Astraea phoebia, L. scabra* and *S. americanus* frequently are found in rocky offshore areas. The fauna at "210 Rock", studied intensively during recent years, is believed to be mainly self-reproducing (personal communication–R. O. Parker). Unusually cold winters in 1977 and 1978 have caused significant mortalities at this rock (pers. comm.–R. Searls); however, the 1978 to 1980 presence of large living specimens of *Charonia variegata* and *Lima scabra* indicates that these two species, at least, are capable of surviving off North Carolina at "210 Rock" even under periods of unusually cold winter stress. Read (1967) in his thermal tolerance study of *Lima scabra* from Puerto Rico, primarily concerned with upper temperature limits, lists a winter adaptation temperature of 26.2°C for the species, a temperature considerably higher than that occurring at "210 Rock". That *Charonia variegata* also seems capable of surviving winter temperatures as low as 6°C, may suggest that it likewise is capable of sustaining a population within North Carolina waters.

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Specimens of *Cooperella atlantica* in the UNC-IMS Collection were compared by the senior author with identified specimens in the molluscan collection at the Delaware Museum of Natural History. Our specimen of *Charonia variegata* (UNC-IMS#4366) was identified by Mr. Russell Jensen of the above institution.

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RECOLONIZATION OF REACTOR COOLING WATER SYSTEM BY THE ASIATIC CLAM *CORBICULA FLUMINEA*[1]

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ABSTRACT

Recolonization rates for the Asiatic clam Corbicula fluminea *ranged from 3.0 to 5.6 metric tons per year in cooling water basins for a nuclear production reactor at the Savannah River Plant. However, a 10-month cleaning cycle for each basin (flow area, 6100 m²) keeps the depth of the silt/clam layer low. With this cleaning frequency,* Corbicula *are not reaching heat exchangers at sufficient size or in sufficient numbers to restrict flow. Data are presented on the size/age distribution for clams recolonizing cooling water basins between cleanings.*

The Savannah River Plant (SRP), built and operated for the Department of Energy by E. I. du Pont de Nemours and Company, was established in 1950 to produce plutonium-239 and tritium for national defense (Harvey and Randall, 1974). SRP occupies an 800-km² area of the Atlantic Coastal Plain near Augusta, Georgia, and is bordered on the south for 35 km by the Savannah River. The Savannah River is the principal source of cooling water for the nuclear reactors used to produce the plutonium and tritium.

The Asiatic clam *Corbicula fluminea* was first reported in the Savannah River near Augusta, Georgia, in 1973 (Fuller and Powell, 1973). Labeled as a pest species by many industries, *Corbicula* are noted for their ability to restrict flow in water supply pipes and to clog ducts and screens. The affected industries are widespread and include water and sewage plants, power generating plants, and irrigation systems (Goss and Cain, Jr., 1975; McMahon, 1977). By 1975, sufficient numbers of *Corbicula* were present in cooling water from the Savannah River to clog the heat exchangers (Fig. 1) of P-Area nuclear production reactor, one of three (P, K, and C) at SRP. Clams were also found in the K- and C-Reactor cooling water systems.

[1]The information contained in this article was developed during the course of work under Contract No. AT(07-2)-1 with the U. S. Department of Energy.

The cooling water for P Reactor comes from two sources: the Savannah River and a cooling water reservoir, Par Pond (Fig. 2). The cooling water for K and C Reactors is pumped directly from the river through a system of pipes into large basins. Juvenile clams apparently enter the system with the river water and are transported 8 to 10 km through pipes before reaching the basins. *Corbicula* have been recently (1981) found in Par Pond.

At K and C Areas, large volumes of river water are discharged into three 32-megaliter basins (Fig. 3) where some settling occurs before the water is pumped through heat ex-

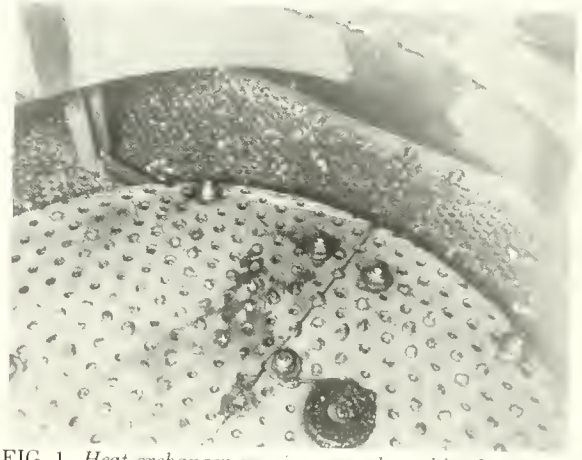

FIG. 1. *Heat exchanger openings are clogged by the Asiatic Clam* Corbicula fluminea.

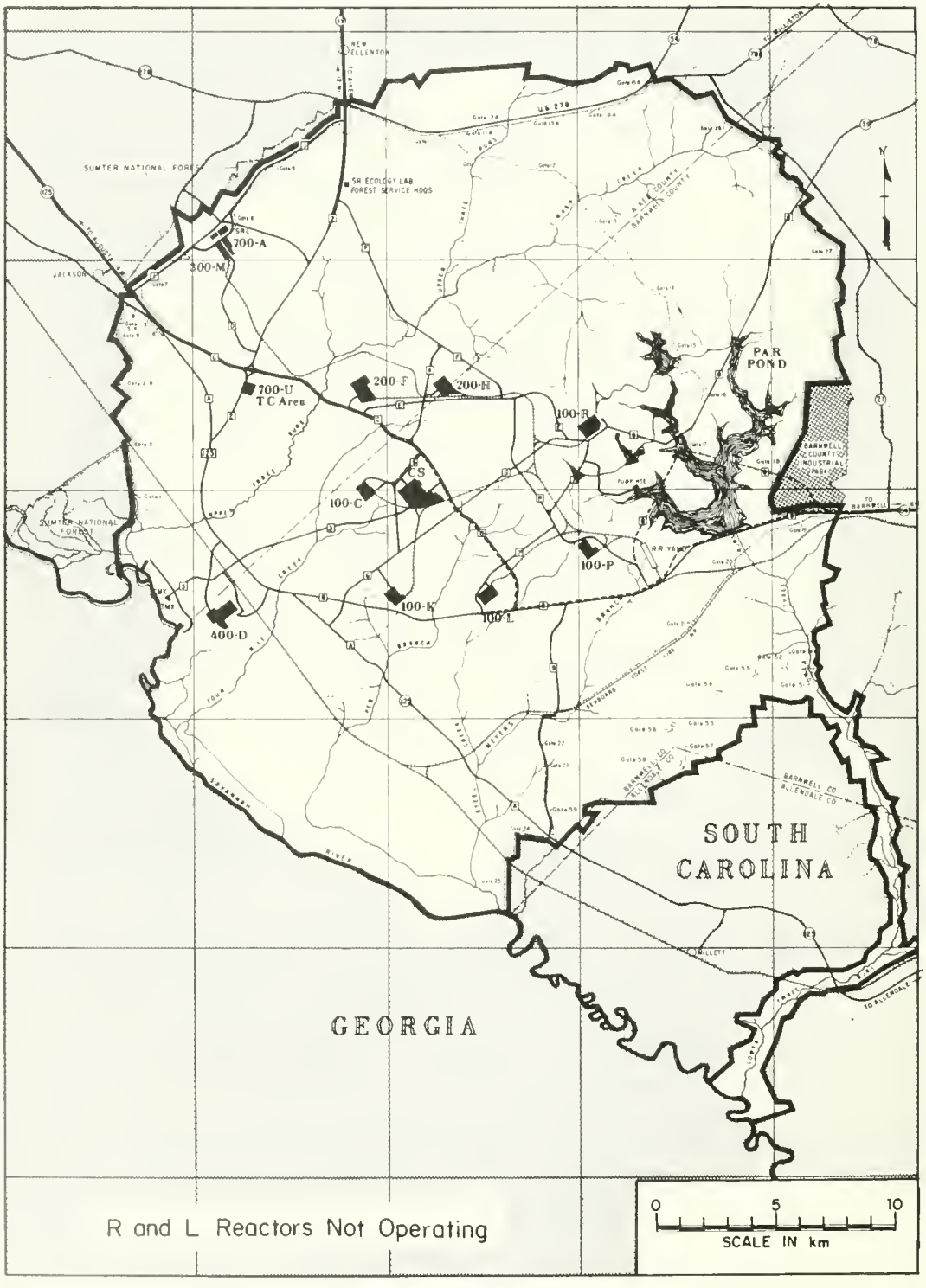

FIG. 2. *Production Areas and cooling water sources on the Savannah River Plant.*

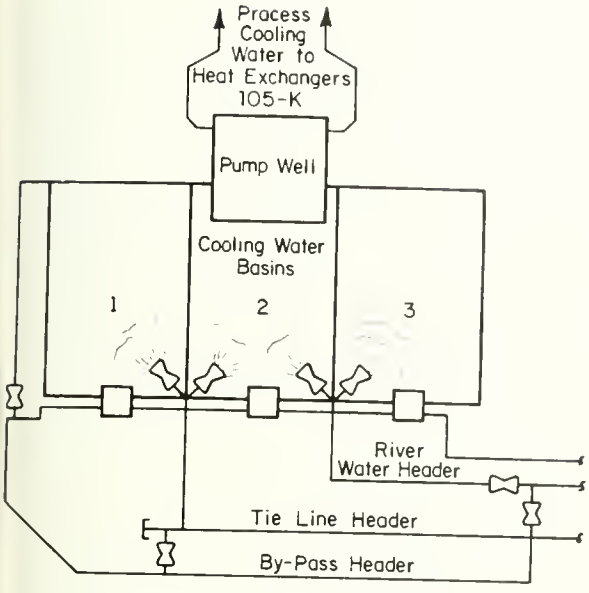

FIG. 3. *K-Area cooling water system.*

changers in the reactor area. The floor area of each basin is approximately 6100 km². Due to infrequent cleanings and unexpected accumulations of *Corbicula*, the silt/clam substrate levels in P-Area basins were about 90 cm deep when heat exchanger pluggage occurred. The substrate levels in K-Area basins in 1976 were approximately 75 cm. The deposited silt and flow of river water provides suitable substrate and nutrients for *Corbicula* growth and reproduction. Silt and clams must be removed at regular intervals to prevent heat exchanger pluggage arising from high populations of clams in the basins. Current practice is to clean the basins every ten months.

A model has been developed to determine the growth rate of *Corbicula* in the cooling water basins at SRP (Pool and Tilly, 1978); their survival in chlorinated water has also been studied (Tilly, 1973). The objective of this paper is to characterize and provide a measure of the *Corbicula* population recolonizing the K-Area cooling water basins between cleanings (October 1976–August 1977).

Method

At present, the clams are controlled by cleaning the reactor basins, pump wells, and emergency cooling system every ten months. Each cleaning occurs during reactor shutdown and involves draining the basins. The walls are washed down with fire hoses and the silt on the floor is removed. The emergency cooling system is also flushed completely at this time.

When the basins were cleaned, clams suspended in basin water were sampled with a 760-μ plankton net, 0.5 m in diameter and 1.5 m long, with a digital flowmeter mounted in the mouth of the net. The net was hand-held near floor drains as water levels dropped from 1.0 to 0.7 m. The sample was examined and clams were measured with the aid of a dissecting microscope.

Quantitative samples from the walls, floors, and pump wells were washed through a U.S. Standard Number 10 sieve to collect the *Corbicula* present. Shell lengths of 100 clams from each sample were measured with a caliper across the widest part of the shell parallel to the hinge; this measurement was then used to determine the approximate age of each specimen (Gardner, et al., 1976).

Results and Discussion

Flow was maintained on at least one of the three cooling water basins at all times. Under normal flow conditions, water is pumped from the pump wells to heat exchangers in the reactor area. Basins 2 and 3 were both drained on 1 September 1977, and were dry, when sampled six days later, except for small areas exposed to leakage. Basin 1 was drained on 28 September 1977, and was sampled during and immediately after draining. Basin 2, located between the other basins, contained essentially no silt and too few clams for a meaningful sample. About 50% of the floor area of Basin 3 was covered with silt up to 12.5 cm deep with an average depth of about 7.5 cm. Clam mortality, based on 5 sample areas (each 100 cm²), ranged from 20 to 80% depending on the moisture of the substrate. Earlier notification would have permitted samples from Basin 3 during draining and would have made results more comparable with those from Basin 1. Mortality was only 5% for

Corbicula collected from pump wells in Basins 2 and 3, and for those collected from Basin 1. About 40% of the floor area of Basin 1 was covered with silt up to 5.0 cm deep with an average depth of 2.5 cm.

Clam concentrations on the floors of Basins 1 and 3 (Table 1) were generally comparable except for the fifth sample from Basin 3 which was taken from a large mound of clams piled up by receding water. By using mean concentrations of *Corbicula*/m² and appropriate percentages of floor area covered by silt, clam populations in Basins 1 and 3, ten months after cleaning, were estimated to be 2.7 and 10.2 million, respectively (calculation excluding sample 5).

Size/age distribution data (Table 2) show that *Corbicula* in Basin 1 were smaller and younger than those in Basin 3. A higher percentage of juveniles and fewer one- and two-year old *Corbicula* in Basin 1 than in Basin 3 may be due to

TABLE 1. Corbicula *concentrations in K-Area cooling water basins.*

	Number of Clams/m² of Sample Area			
	Basin 1		*Basin 3*	
Sample	*Basin Floor*		*Basin Floor*	*Suction Well*
No.	*Sept. 1977*	*Aug. 1978*	*Sept. 1977*	*Sept. 1977*
1	3002	23270	4380	11780
2	1076	11580	505	30380
3	656	7061	2130	18600
4	1431	15403	6230	-
5	430	4628	44780[1]	-

[1]Sample 5 was collected from a mound of clams accumulated by receding water. The sample is not representative of clam concentrations in the basin.

TABLE 2. *Size distribution of* Corbicula *in the K-Area cooling water basin.*

	Shell Length/Age Class (Percent of Population)			
Location	*<7.5 mm (<1 yr)*	*7.5 - 13.5 mm (1 yr)*	*13.6 - 18.5 mm (2 yr)*	*18.6 - 28.0 mm (3 yr)*
186-1K Basin				
Floor, Sept. 1977	78.3	14.9	6.8	0.0
Water[1]	100.0			
186-3K Basin				
Floor	9.4	73.9	16.7	0.0
Suction Well	17.5	48.3	29.2	5.0
K-Area ECWS				
CW-39	1.0	37.0	39.0	23.0
RW-1	1.0	59.0	39.0	1.0

[1]Shell lengths are <1 mm (151 specimens).

the source of cooling water. Basins 2 and 3 are supplied from the river water header; Basin 1 is supplied from a tie line header which has a section of pipe with stagnant water. This would suggest that the juveniles might be produced or raised in the tie line.

The silt substrate in the pump wells of Basins 2 and 3 generally contained higher concentrations of *Corbicula* (Table 1) than were found in basin floor samples. The reason is not known. Size/age distribution data for clams from the pump well (Table 2) are comparable to those observed for clams in Basin 3.

Wall scrapings in the K-Area basins did not yield any *Corbicula*. Samples (100-cm^2 areas) were collected at various depths and washed through a U.S. Standard Number 10 sieve.

Corbicula larvae, generally smaller than 250 μ, were not found in the K-Area basins. Shell lengths of 151 juveniles collected from 400 kiloliters (kL) of water during the draining of Basin 1 ranged from 380 to 1000 μ (1 kL = 264.18 gallons; 1 μ = 0.001 mm). These specimens were collected in a 715-μ plankton townet as the water level dropped from 1.0 to 0.7 m. This collection represents a concentration of about 0.4 clams/kL or 12,618 clams per basin volume.

An analysis of the size/age distribution data (Table 2) shows that *Corbicula* grow about 600 to 1100 μ/month during the first year. On this basis, the juveniles collected from Basin 1 were probably produced in late August or early September 1977, just prior to the draining of the basin. The *Corbicula* spawning season begins when the water temperature reaches 16 to 17°C and continues until temperature falls below this (Gardner et al., 1976), thus allowing a spawning season in the Savannah River usually from April through November. However, the origin of these clams can only be speculated. They could have entered the basins as larvae or as juveniles by transport through distribution pipes, or they could have been produced as larvae by adult *Corbicula* living on the floor of Basin 1.

An experiment in October 1977 estimated the transport of *Corbicula* from the raw water system into Basin 1. Immediately after the basin was drained, the walls and floor were washed with fire hoses to remove all clams. The basin was refilled on 6 October 1977, and the water was allowed to stand for two hours for the clams to settle before draining for the second time. Four *Corbicula* juveniles with shell lengths about 0.5 mm in length were found in a 129-kL plankton townet sample (mesh 715 μ) collected from Basin 1 as the water level dropped from 1.0 to 0.7 m. This calculates to about 0.03 clams/kL or 946 clams/basin volume. When the basin was completely drained, the basin floor contained very little silt and only a few clams near the inlet header and near the effluent drain. Six 1-m^2 floor samples yielded *Corbicula* concentrations of 0, 0, 4, 12, 2, and 0/m^2. One specimen was less than 1 year old, seven were about 1 year old, and ten specimens were approximately 2 years old. This experiment demonstrates how quickly a clean basin can be restocked with both juveniles and sexually mature clams from the river water header.

Summary

The ten-month cleaning cycle is effective in preventing the buildup of silt/clam substrate in K-Area basins. The level in 1976 was about 75 cm; in both 1977 and 1978, silt/clam levels were <15 cm. Although clams are recolonizing Basins 1 and 3 at rates of 3.0 and 5.6 metric tons/year, clams apparently are not reaching the heat exchangers at sufficient size or in sufficient numbers to restrict the cooling water flow. A higher percentage of juvenile clams in Basin 1 (78%) than in Basin 3 (9.4%) may be due to Basin 1 receiving water from the tie line header which has a section that is not routinely flushed to remove clams.

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THE REPRODUCTIVE SYSTEM OF THE WESTERN ATLANTIC *ANACHIS AVARA* (GASTROPODA: COLUMBELLIDAE)

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ABSTRACT

The reproductive system of specimens of Anachis avara *(Say, 1822) from Biscayne Bay, Florida, is described from dissections and histological sections, and found similar to that of its southern counterpart,* A. brasiliana. *In this case it appears that the reproductive systems are of little taxonomic value at the specific level.*

Few investigations have been made regarding the functional anatomy of reproductive systems in the Columbellidae. Marcus and Marcus (1962b) studied the genitalia of eight species from Brazil. In a later study, Marcus and Marcus (1964) compared the external shell characteristics and the genital system of *Anachis pulchella* (Blainville 1829) with those species previously investigated. Houston (1976) described the reproductive systems of several species from the Gulf of California.

Anachis avara (Say, 1822) is a small prosobranch of the family Columbellidae reported by Radwin (1977a) to have a geographical range from the Gulf of Maine to Miami, Florida. In Brazil and Uruguay this species is replaced by *A. brasiliana* (von Martens, 1897) one of the eight species studied by Marcus and Marcus (1962b). Abbott (1974) considered *brasiliana* to be a subspecies of *avara*. Recently, Radwin (1977a, 1977b) placed these species in the genus *Costoanachis* Sacco, 1890. However, in this study, we treat *Costoanachis* as a subgenus of *Anachis*.

It is the objective of this study to determine if there are differences in the reproductive anatomy, which are useful in distinguishing *Anachis avara* from *A. brasiliana*. In addition, the major anatomical and functional aspects of the genitalia of *A. avara* will be discussed, in relation to other neogastropods.

Methods and Materials

Both sexes of *Anachis avara* were collected from the shallow subtidal of Biscayne Bay, Florida. Gross anatomical features of the reproductive system were determined by means of dissections of living and preserved material. In addition, stained serial sections were used to elucidate the histological details. Through the use of standard histological techniques, the animals were infiltrated with paraffin and sectioned at 8 microns. The sections were then stained with Weigert's Hematoxylin and

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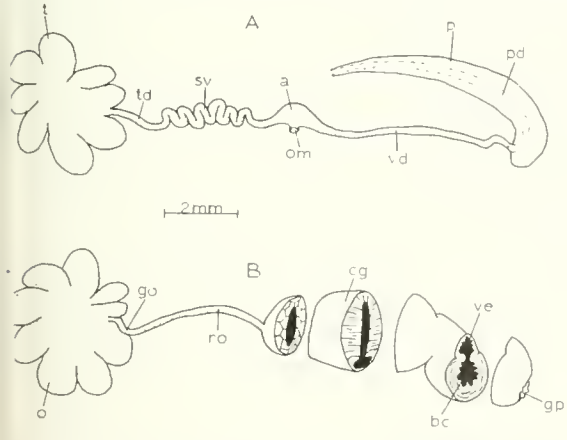
Gomori's Trichrome following the procedure of Gomori (1950).

Results

The Male Duct

Posteriorly, both the testis (t) and digestive gland share the visceral mass. The testis is composed of numerous acini which are surrounded and separated from each other by a thin layer of loose connective tissue. Mature spermatozoa occur within each acinus. They are arranged in an orderly fashion with their heads embedded in the acinar epithelium and their tails extending into the center of the lumen.

These acini lead to acinar ducts which ultimately join to form the testicular duct (td) (Figure 1A). Anteriorly, the testicular duct runs along the columnar region of the whorls next to the digestive gland until it becomes highly convoluted. This coiled region, now the posterior vas deferens, appears to function as a seminal vesicle (sv) for it is densely packed with sperm. The lumen is lined with low columnar epithelium which have round basal nuclei. In addition, the cytoplasm contains light blue granules which may be secretory in nature. Furthermore, this duct is approximately 2.5 mm long and attains the same diameter throughout its length. As the seminal vesicle approaches the posterior region of the mantle cavity, it straightens out for a short distance then opens into a large thin-walled ampulla (a). This structure corresponds to the seminal vesicle of Brasilian columbellids studied by Marcus and Marcus (1962b). From this sac there is communication with the mantle cavity (om) by means of a short ciliated duct. This duct is 70μ long and its entrance into the sac is guarded by a sphincter.



IG. 1. *Genitalia of* Anachis avara: **A-** *male,* **B-** *female.* **a**-*ampulla;* **bc**-*bursa copulatrix;* **cg**-*capsule gland;* **go**-*nadal oviduct;* **gp**-*genital pore;* **o**-*ovary;* **om**-*opening into antle cavity;* **p**-*penis;* **pd**-*penial duct;* **ro**-*renal oviduct;* **sv**-*minal vesicle;* **t**-*testis;* **td**-*testicular duct;* **vd**-*vas deferens;* **e**-*vestibule.*

Anteriorly the sac or ampulla leads to a thick-walled muscular ciliated duct, the anterior vas deferens (vd). This tube runs along the right body wall until it joins the penis (p). The penis, which is located just posterior to the right cephalic tentacle, is extremely long and dorsoventrally flattened. Furthermore, it is wide at the base and then tapers to a point. The wall of this organ is composed of an outer layer of circular muscle cells. Inside are two layers of longitudinal muscle fibers from which arise additional fibers that form a latticework around the haemal sinuses. Finally, the entire structure is covered with a single layer of ciliated squamous cells. The penial duct (pd) is centrally located and appears as a convoluted tube which opens at the tip of the penis. Histologically the penis can be divided into two regions. At the base it is lined with glandular cells interspersed with ciliated tall columnar cells. The basal round nuclei of the gland cells are highly basophilic and have two nucleoli. The ciliated cells, in turn, have oval nuclei which are centrally located. Anteriorly, the lumen of the penial duct is lined entirely by secretory epithelium. As in other columbellids (Marcus and Marcus, 1962b; Houston, 1976), the tip of the penis is tucked in a pouch in the posterior mantle wall.

The Female Duct

The bright yellow ovary (o) lies along the outer side of the visceral mass and is separated from the digestive gland by a thin layer of connective tissue. In addition, there is a tenuous layer of connective tissue surrounding the ovary itself. As in the testis of the male, the ovary is composed of numerous acini which collectively funnel into the gonadal oviduct (go) (Figure 1B). Several cell types comprise the acinar epithe-

lium. These include low columnar cells, secretory cells, primoidal germ cells and developing oocytes. Within the acinar lumina are oocytes that are attached to the epithelium by a peduncle. Also, there are large numbers of oval secretory droplets that stain bright red with Gomori's.

The short thin-walled gonadal oviduct is lined with nonciliated low columnar epithelium and in mature females it is packed with oocytes. As this tube leaves the visceral mass it becomes ciliated and becomes the renal oviduct (ro). Here it straightens out and runs anteriorly along the right side of the body wall, just ventral to the nephridium and dorsal to the pericardial cavity. Anterior to the pericardial cavity the oviduct enters the posterioventral region of the large capsule gland (cg).

In cross section this organ has a lumen which appears as a dorsoventral slit that divides it into right and left lobes. The lumen is lined with ciliated, tall, columnar epithelium interspersed by ducts arising from clusters of subepithelial gland cells. It is interesting to note that two subepithelial cell types, each with their respective staining properties, occur within the gland.

The posterior one-fourth of the gland is composed mainly of polygonal cells with small round centrally located nuclei. Moreover, the cytoplasm stains bluish-green with Gomori's. The rest of the capsule gland is made up of elongated clusters of teardrop-shaped cells that stain deep red. In addition, within the lumen are masses of secretory droplets of the same color.

Anteriorly, the lumen of the capsule gland is continuous with a large deeply folded vestibule (ve). It is rather thin-walled and lined with ciliated, low, columnar epithelium. Ventral to and communicating with the vestibule is the highly muscular bursa copulatrix (bc). This organ is lined with ciliated, low, columnar epithelium like that of the vestibule, except the cilia are shorter and not as numerous. The vestibule and bursa copulatrix both join anteriorly in the form of a short ciliated vagina which terminates at the genital pore (gp).

DISCUSSION

As far as one is able to determine, the reproductive system of *Anachis avara* is like that of *A. brasiliana* as described by Marcus and Marcus (1962b). It is therefore apparent that, in this case, the reproductive system is of little taxonomic value at the specific level. Differences in reproductive anatomy, do occur among higher categories.

Marcus and Marcus (1962b) concluded there are two morphological divisions among the Columbellidae, based on their reproductive systems. One group contains species in which the males have a seminal vesicle and no prostate gland; and females that have an albumin gland and bursa copulatrix. The other group contains species in which males do not have a separate seminal vesicle but have a prostate gland. Moreover, the females lack an albumin gland and bursa copulatrix, but they have a gonopericardial connection. In following this scheme, *Anachis avara* and *A. brasiliana* would belong to the former group.

It is worth noting that *Anachis avara* and the columbellids studied by Houston (1976) appear to have generalized reproductive systems with specific regions performing more than one function. Thus, compartmentalization is not to the degree as in other neogastropod groups. These include: the Muricidae, Nassariidae and Buccinidae studied by Fretter (1941), and the Turridae examined by E. H. Smith (1967). In these groups the separate organs each appear to assume one function.

In male columbellids the coiled posterior vas deferens appears to function both as a seminal vesicle and for resorption of sperm. This condition also occurs in those species that appear to have a separate seminal vesicle. Furthermore, the penis probably has a dual function. In addition to being an intromittent organ, the presence of glandular tissue indicates it may assume a prostatic function. The bursa copulatrix in females receives the penis during copulation (Houston, 1976). Moreover, it functions as a depository for spermatozoa, although no sperm were present in females of *Anachis avara*. Observations by Marcus and Marcus (1962b) indicate that in some species of columbellids, the bursa is divided into two sacs. One sac serves as

a site for sperm ingestion, while the other is used for storage.

The albumin gland of *Anachis avara* and other columbellids is not externally separated from the capsule gland, but occupies the posterior region of the latter. This also appears to be the case for some species of olivids (Marcus and Marcus, 1959). This arrangement differs from other families of neogastropods where a short duct separates the two glands. Some of these families are: Muricidae, Nassariidae and the Buccinidae (Fretter, 1941), the Terebridae (Marcus and Marcus, 1962a), and the Turridae (E. H. Smith, 1967). In addition, Ponder (1970) found this to be true for the volute, *Alcithoe arabica* (Gmelin, 1791). Also, a later study by Ponder (1972), showed this to be the case for the Mitridae. More recently, Fretter (1976) indicated that a deep constriction separates the capsule and albumin glands in the marginellid, *Volvarina taeniolata* Mörch, 1860.

Therefore, it appears that two major morphological types of genital systems occur throughout the neogastropods. One specialized type with high compartmentalization and numerous accessory organs, each apparently performing a particular function; and a second generalized type with low compartmentalization and fewer accessory structures which assume multiple functions. Whether one type is more advanced than the other is difficult to determine.

Recently, Radwin (1977a) mentioned that the Columbellidae exhibit a high degree of adaptive radiation in shell morphology. Since they have invaded numerous habitats, possibly they would have evolved specialized organ systems to adapt to these habitats. This does not appear to be the case in their reproductive anatomy. On the other hand, since the Columbellidae originated during the Eocene and radiated as recently as the Miocene (Radwin, *Op. cit.*), it is possible there has not been enough time for specialized systems to evolve. If there was ample time for specializations to occur, they could possibly have been lost. In any case much work is needed on the functional and ecological interrelationships of reproductive systems.

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GROWTH RATE DETERMINATIONS OF *ACHATINELLA LILA*, A HAWAIIAN TREE SNAIL

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Hawaiian tree snails of the family Achatinellidae are described by Pilsbry, et al. (1912–1914). The species studied in this paper is *Achatinella lila,* the habitat of which is the summit area of the Koolau mountains on the Island of Oahu. Little is known about the biology of these snails, therefore this study was undertaken to determine their growth rates.

Materials and Methods

The altitudes of the colonies range from 2,500 feet to 2,800 feet. The colonies were all located on ohia trees *(Metrosiderus polymorphus)* and the surrounding low shrubs and vines. Specimens were taken from three colonies, each of which was characterized by a distinctive overall color: brown, yellow, or green. All of the snails were banded with either yellow or brown.

A total of 56 animals was collected – 20 from the predominantly yellow colony, eight from the predominantly green colony, and 28 from the predominantly brown colony. The green and the yellow colonies were from the same immediate area and altitude, the brown from a slightly lower elevation.

Because *A. lila* had not been kept in captivity successfully before, some details of the means of doing so are presented here. The collected snails were reared in cages which were 30 × 18 inches on the base and 20 inches high, and made of screen on a pine frame. Three cages were constructed to permit isolation of the individual colonies so that no cross-breeding among colonies could occur. Because the cages were kept at a high humidity, there was a possibility that disease-causing bacterial colonies might form. To avoid this, the cages were placed in a slight draft and partial sunlight. The snails feed naturally on algae and fungus species growing on the surface of smooth-leafed plants. As permanent substrate for the snails, Hawaiian bird nest ferns *(Asplenium nidum)* were kept potted in the cages. The ferns required minimal sunlight and provided a large smooth leaf surface for grazing snails. The snails do not eat the ferns.

The snails were fed a mixture of lettuce and dried milk. By blending the lettuce leaf and the dried milk with water, a paste that could be lapped up by the snails from the surface of the substrate plants was made. This mixture was marginally acceptable by two of the varieties, while the third, the green variety, seemed to do well.

All three varieties formed a growth scar while adjusting to the artificial nutrient mixture. This scar is a convenient mark with which to measure growth. Two scars were present on the shell at the end of the first month after collection. The first scar was formed after birth and marked the end of the nuclear whorl. The other scar was formed as a result of the nutritional changes described above. Several snails were born to the colonies during the initial period of captivity, and these shells showed none of the scarring due to the artificial food.

The artificial food was replaced eventually by natural food (fungus and algae found on the bark and leaf surfaces of forest trees) to insure the life of the snails born in captivity and to allow growth to continue at as near normal rate as possible. The snails were fed in captivity and observed for several months.

Growth measurements were taken on a total of 32 shells. Six of these were born in captivity and placed in individual size classes to the nearest 0.5 mm. The rest were grouped in 1.0 mm size classes, beginning at 11.0 mm (see Table I).

Growth was measured along the suture (Fig-

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Table 1.

Shell Size apex to base (mm).	Suture Growth per size class (mm).	Average suture growth per size class (mm).	Number of days of observation	Suture Growth rate per day (mm).
*03.0	0.345		4	0.086
*03.5	1.4		20	0.070
*04.5	2.2		39	0.056
*05.0	2.3		47	0.049
*07.0	1.8		52	0.035
*08.0	2.1		72	0.029
11.0	3.0 1.6 4.6	2.3	81	0.028
12.0	3.0 2.5 3.0 1.0 9.5	2.4	81	0.029
13.0	2.5 3.0 1.5 2.1 2.0 11.1	2.22	81	0.027
14.0	2.0 2.0 1.5 1.5 1.8 2.0 1.0 11.8	1.7	81	0.021
15.0	1.6 1.5 1.7 1.6 6.4	1.6	81	0.020
16.0	2.0		81	0.025
17.0	1.2 2.0 3.2	1.6	81	0.020

*Born in captivity.

ure 1) of the shell, beginning at the scar formed from change in diet when the animals were taken into captivity. A thin piece of thread was used to measure the suture growth. Calipers were used to measure the overall length of the shell. An average of growth rate for each size class was calculated, and this was then divided by the number of days since scarring had occurred to give an estimate of daily growth rate. This measurement was compared with the total length of the shell from apex to base. Figure 2 shows the relationship of these two measurements. The procedure was repeated with animals which had been born in captivity and whose shells showed no scarring. The average growth rates of the latter series of snails also were com-

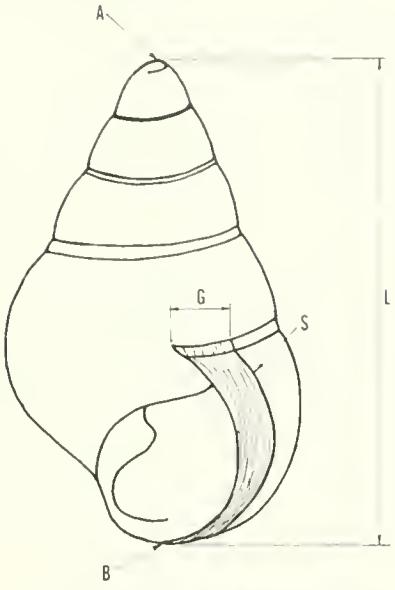

FIG. 1. *The shell measurements used in the paper:* **A**, *the apex of the shell.* **B**, *the base of the shell.* **G**, *the growth along the body whorl of the shell.* **L**, *the length of the shell from apex to base, and* **S**, *the scar formed by the change in nutrition from the natural food to the artificial food.*

pared with the length of the shells determined from apex to base. This series of young individuals provided the growth rate data for the beginning of the curve.

Results

Table I presents growth data from the snails. The first column lists the different size classes into which the snails were put according to their shell length (Figure 1). The second column shows the individual growth measurements of the snails in each size class. These measurements were averaged in those size classes with more than one individual (third column). The fourth column shows the growth period in number of days. The growth, or average growth, of the snails during the observed growth period was then divided by the number of day of observation giving a value in millimeters which represents the average growth per day of the shells. This latter value was plotted against shell length to obtain the curve (Figure 2), which shows changes in the growth rate as the snail matures.

This growth rate curve shows a rapid decrease in growth rate as the shell length increases. The shell length at which the growth rate begins to level off is approximately 9 mm. The length of

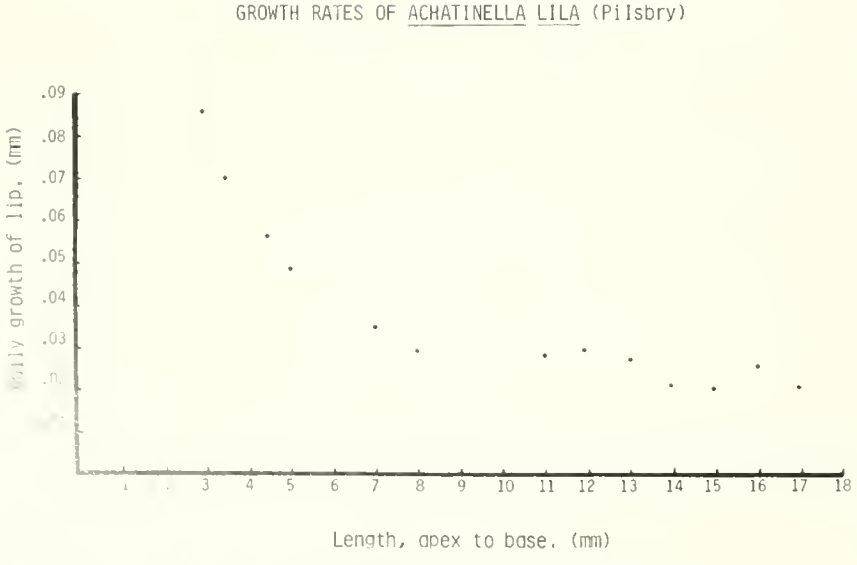

FIG. 2. *Growth rates of* Achatinella lila *(Pilsbry).*

the shell eventually almost doubles to 17 mm but with a much slower growth rate. The smaller and younger snails grow much faster than the larger snails.

Three-millimeter shells, which is the size at birth, have a growth rate of .086 mm/day. At 5 mm the daily growth rate has declined to .049 mm/day and at 8 mm to .029 mm/day. The growth rate then decreases from .028 mm/days to .020 mm/days for shells 11 mm to 17 mm respectively (Table I).

DISCUSSION

With the data collected and calculated, it became clear that age approximations for each shell class could be figured. Table II follows the progression of data from the size class to the age in days of the shell at that size class.

In column 1 the size classes of shells, measured apex to base, are listed. Choosing one of these classes, 15 mm, the suture of the shell was measured from the end of the nuclear whorl around the whorls to the end of the body whorl. This is shown in column 2 as 53 mm. Next, the suture of the preceding size class, 14 mm, was measured and subtracted from the length of the suture of the shell of the class of 15 mm shells. Thus an increase of 4 mm in suture length is then listed in column 3. The next step involves utilizing the data from the last column of Table I, the daily growth rate of the shell along its suture. The daily growth rates of the preceding class, 14 mm, and of the 15 mm size class, .021 mm and .020 mm respectively, were averaged to obtain .021 mm, representing the growth rate from one class to the next. Finally, in column six the number of days to advance from one class to another was figured. This was obtained by dividing the suture length difference of column 3, 4 mm, by the average growth rate between size classes, .021 mm/day. The final column is the accumulated number of days from birth of the snail to the size class being observed; class 15 mm is 1,404 days old or 3.85 years old.

It can be seen from the data, then, that the oldest and largest of the snails studied is 17 mm in length, and has reached an estimation age of 5.27 years. This suggests that the life span of the snails can be five years.

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Table II.

(All measurements in mm unless indicated.)

Shell length (size class).	Total suture length.	Increase in suture length per class.	Observed suture growth rates per day.	Average daily suture growth rates between classes.	No. of days between each size class.	Total days for each group.
7mm	13mm	---	.035mm		---	---
8	18	5mm	.029	.032mm	72 days	---
9	23	5	---	.029*	172*	244 days
10	29	6	---	.028*	214*	458
11	33	4	.028	.028*	143	601
12	39	6	.029	.028	214	815
13	42	3	.027	.028	107	922
14	49	7	.021	.024	292	1214
15	53	4	.020	.021	190	1404
16	60	7	.025	.023	304	1708
17	65	5	.020	.023	217	1925

*Estimates

$\frac{5.27 \text{ years}}{365/1925 \text{ days}}$

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AN ELECTROPHORETIC AND MORPHOLOGICAL SURVEY OF *BUSYCON* OCCURRING IN WASSAW SOUND, GEORGIA

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ABSTRACT

Sixty-seven specimens of right-handed knobbed whelks collected in Wassaw Sound, Georgia were examined for genetic and morphological variation in order to determine the validity of the taxa Busycon carica *(Gmelin, 1791) and* Busycon eliceans *(Montfort, 1810). Starch gel electrophoresis was run on 23 enzyme systems; of these, six were used for data collection: SOD, LAP, MDH, PGI, and 6-PGD. They were all found to be monomorphic. Four shell characters: tumidity, knobbiness, aperture coloration, and the ratio of aperture length to overall shell length were also examined. No association between these characters was found and the sample was normally distributed. Only 34.3% of the specimens could be classified as belonging to* B. carica *or* B. eliceans *exclusively. Therefore from this electrophoretic and morphological evidence, we determined the sample to have been taken from a single population of* B. carica *and use of the taxon* eliceans *in this locale is unnecessary.*

The knobbed whelk, *Busycon carica* (Gmelin, 1791), is a large (125 to 225 mm) carnivorous gastropod common in estuaries from Cape Cod, Massachusetts, to Cape Canaveral, Florida (Abbott, 1974). The name *Busycon eliceans* (Montfort, 1810) refers to a similar form commonly found in the southern part of the range of *B. carica*, from North Carolina to Cape Canaveral (Pulley, 1959). *Busycon carica* and *Busycon eliceans* were classified by Hollister (1958) as a pair of sympatric species, and later reclassification placed the taxon *B. eliceans* as a subspecies of *B. carica* (Abbott, 1974).

The adult forms of *B. eliceans* have previously been separated from *B. carica* on the basis of three morphological characters: presence of tumid ridge, prominent spines as opposed to low tubercles, white aperture coloration with yellow to brown suffusions as opposed to the orange aperture color in *B. carica*. In this paper all spines, knobs, and tubercles are referred to as degrees of knobbiness.

Both described forms of the knobbed whelks are found in Wassaw Sound, Georgia. We examined individuals from this area in order to determine their morphological and genetic variation and to see if separation of these individuals into populations of *B. carica* and *B. eliceans* is applicable. Protein electrophoresis was employed to determine genetic differences be-

tween individuals for comparison with their morphological characteristics. Electrophoresis has been successfully used to distinguish closely related molluscan taxa (Chambers, 1978; Skibinski *et al.*, 1977). The morphological traits applied are those typically used by malacologists for species distinction. The niche, historical age, habitat and abundance of the animal led us to believe that electrophoretic techniques might detect considerable genetic variation.

Large differences in shell form, coloration and sculpture exist among local populations, members within a single population and even in single individuals (Pulley, 1959; Stanley, 1979). *Busycon* is a wholly North Atlantic genus that has flourished in this region since the lower Miocene epoch (Hollister, 1958). *Busycon* are found in abundance from intertidal flats where their prey, oysters *(Crassostrea virginica)* and clams *(Mercenaria mercenaria)* are numerous to approximately the 26 fathom contour offshore (Walker, in prep.). The genus seems to be made up of localized populations of slow-growing long-lived animals, and gene flow between different populations could be slow or even negligible (Pulley, 1959). Individuals are continually migrating between adjacent intertidal flats as a result of prey availability and on and offshore seasonally (Walker *et al.*, 1980).

The estuarine habitat is not homogeneous in structure or in physical, chemical or biotic characteristics. Fluctuations of salinity, turbidity, water depth and temperature greater than those in the open sea are encountered (Vernberg, 1972). Considerable controversy exists concerning the relationship between environmental stability and genetic variability. Based on theoretical argument, Valentine (1976) and Levins (1968) conclude that unstable environments should be inhabited by organisms having higher genetic variability than organisms inhabiting stable environments. Levinton (1973) contributed experimental support to these hypotheses by demonstrating that, for different species of bivalve molluscs, varying and heterogeneous environments did support species that were more polymorphic than those in non-varying, geologically permanent environments. Lewontin (1958) demonstrated a loss of chromosomal polymorphism in a population of *Drosophila pseudoobscura* raised for many generations in a constant environment and concluded that heterogeneous environments retard the loss of genetic polymorphism. Increased heterozygosity has also been correlated with increased benthic ecosystem diversity and with the stability of trophic resources (Selander, 1976; Valentine, 1976; Ayala and Valentine, 1977). *Busycon*, being a geologically old genus, living as it does in a temporally heterogeneous estuarine environment and experiencing spatial heterogeneity through its migratory behavior, appears to fit all the criteria necessary for the maintenance of electrophoretically and morphologically polymorphic populations.

Methods and Materials

All specimens of *Busycon* were collected from Wassaw Sound, Georgia, in April, 1980 and kept frozen until used. Tissue samples were dissected from partially thawed specimens, ground and then run on starch gels. Morphological measurements taken for comparison with electrophoretic findings were: overall length, aperture length, width, presence or absence of a tumidity across the back of the siphonal canal, direction of knobs on the whorls, extent of knobbiness, and color of the aperture. Measurements of shell width, overall length and aperture length were taken using metric calipers. Presence or absence of a tumidity (Fig. 1) and direction of

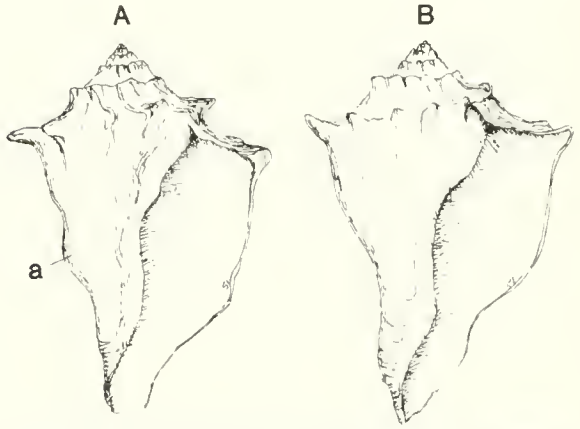


FIG. 1. *The presence (A) or absence (B) of a tumidity (a) across the back of the siphonal canal of* Busycon.

knobs on the shoulder of the whorls (Fig. 2) were recorded. Color hues were determined by eye according to predetermined standards. Examination of radula dentition was made.

The Hunter-Markert zymogram technique combines electrophoresis with histochemical staining methods (Brewer, 1970). The electrophoretic frequencies observed were converted to allelic frequencies for genetic inferences. The enzymes studied by this method were chosen by the availability of appropriate staining techniques and not with regard to the functions they specify.

Horizontal starch gel electrophoresis was used following the procedure of Schaal and Anderson (1974). Ground tissue samples absorbed on 3 by 6 mm filter paper wicks were set in the gel and 55 ma currents were passed across the gel by a model IP-2717 Heathkit power supply for five hours.

Initial samples of liver, kidney, heart, and radula retractor muscles were run on starch gels using six different buffer systems at varying pH regions. These gels were stained for 23 enzyme systems. Lithium Hydroxide, Tris-HCl and JRP buffer systems (John Avise, personal communication), Dehydrogenase and Tris-citrate buffer systems (Schaal and Anderson, 1974), and Poulik Discontinuous buffer system (Poulik, 1957) were examined in conjunction with the following stains: Isocitrate Dehydrogenase, Lactate Dehydrogenase, Malate Dehydrogenase (MDH), 6-Phosphogluconate Dehydrogenase (6-PGDH), Glucose-6-Phosphate Dehydrogenase, Alcohol Dehydrogenase, Xanthine Dehydrogenase, α-Glucose Phosphate Dehydrogenase, Sorbital Dehydrogenase, Phosphoglucose Isomerase (PGI), Phosphoglucomutase (PGM), Glutamate Oxaloacetate Transaminase, Leucyl Amino Peptidase (LAP), Hexokinase, Nucleoside Phosphoralase, Creatine Kinase, Peptidase, Alkaline Phosphatase, Acid Phosphotase, Adenylate Kinase, Esterase α-Naphthylacetate, Superoxide Dismutase (SOD), Malic Enzyme and General Protein (Schaal and Anderson, 1974; John Avise, personal communication). The systems that produced the most clearly defined bands in the initial experiments, were chosen for data analysis. SOD, LAP and MDH stains were used in conjunction with the Tris-citrate buffer system, PGM and 6-PGDH were used with the JRP buffer system, and PGI was used with the Dehydrogenase buffer system.

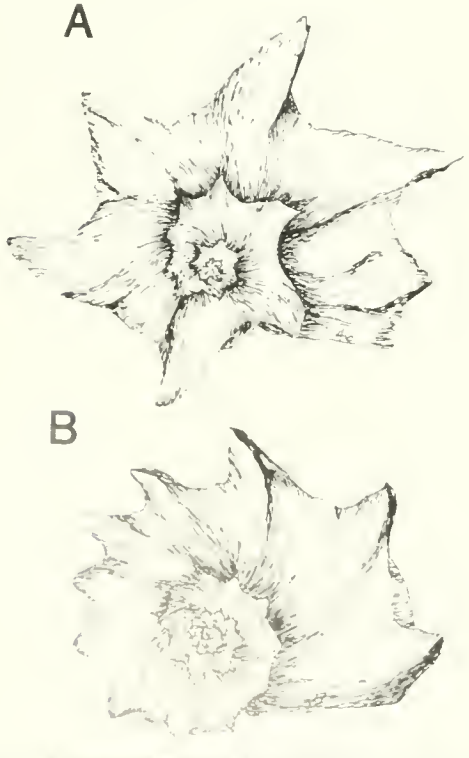


FIG. 2. *Direction of the [illegible] of the whorls. A. forwardly directed. B. [illegible]*

Results

A summary of the morphological observations shows that of the 67 specimens examined, 64 were females (determined by lack of penis and presence of enlarged nidamental glands), 34 possessed recurved spines, 14 had both recurved spines and spines directed forward, and 19 had all forward directed spines. Thirty shells displayed tumid ridges and 37 lacked them. There were 20 pale yellow, 23 yellow, 21 orange and three red apertures observed. The denticulation on the rachidian varied from four to eight while the laterals all had two large cusps on the marginal and central ends separated by two, three or four small denticles. Other workers

have found varying male to female ratios for these snails 1:11 (Walker, in prep.), 1:1, 1:2, 3:1 and 2:1 (Magalhaes, 1943).

Contingency Chi-square tests were used to determine independence of the morphological traits; direction of knobs, presence of tumidity, and aperture coloration, while "goodness of fit" tests were used to ascertain normality of the population (Bhattacharyya and Johnson, 1977; Mendenhall, 1968). There is considerable variation in the size and degree of knobbiness (Hollister, 1958; Magalhaes, 1943) leaving these characteristics undiagnostic. Direction of knobs was determined to be independent of both the presence of tumidity, and aperture coloration at the 0.05 confidence level: knobs/tumidity, $\chi^2 = 0.71$, d.f. = 2 (Table 1); knobs/aperture coloration, $\chi^2 = 7.66$, d.f. = 6 (Table 2). Tumidity and aperture coloration were not shown to be occurring independently at the 0.05 confidence level; $\chi^2 = 11.71$, d.f. = 3 (Table 3). Additional testing of these data by both Cramer's contingency coefficient and Pearson's coefficient of mean square contingency indicated no strong associations between variables and leaves the above mentioned dependence uninterpretable. These values were 0.17 and 0.39 respectively. The sample ratios (N = 67) of overall length to aperture length were found to be normally distributed at the 0.05 confidence level; $\chi^2 = 7.65$, d.f. = 7 (Table 4).

The denticulation on the rachiglossate radula varied greatly but bore no correlation to the size of the individual. There was also no observed correspondence between an increased number of denticles on the rachidian and lateral teeth. The numbers observed for rachidian denticles were: 20 individuals with four denticles, 27 with five, 13 with six, three with seven and one with eight denticles. The denticulation on the lateral teeth varied less; there were four individuals with four, 46 with five, and 14 with six. Some of the radulas are illustrated in Figures 3 to 8. The variations observed in knobbiness, aperture coloration, and number of denticles in the radular teeth corresponds to those found by Magalhaes

TABLE 1. *Contingency Table using the Chi-square "goodness of fit" test for the Null Hypothesis that the two variables, Tumidity and Direction of Knobbation, are independent of each other. Expected frequencies are listed in parenthesis next to observed frequencies.* $\chi^2 = 0.71$, *d.f. = 2, at 0.05 confidence level.*

Tumidity Knobs	Present	Absent	Totals
Forward	7 (8.57)	12 (10.49)	19
Recurved	16 (15.22)	18 (18.78)	34
Both	7 (6.27)	7 (7.73)	14
Totals	30	37	67

TABLE 2. *Contingency Table using the Chi-square "goodness of fit" test for the Null Hypothesis that the variables, Direction of Knobbation and Aperture Coloration, are independent of each other. Expected frequeneies are in parenthesis next to the observed frequencies.* $\chi^2 = 7.66$, *d.f. = 6, 0.05 confidence level.*

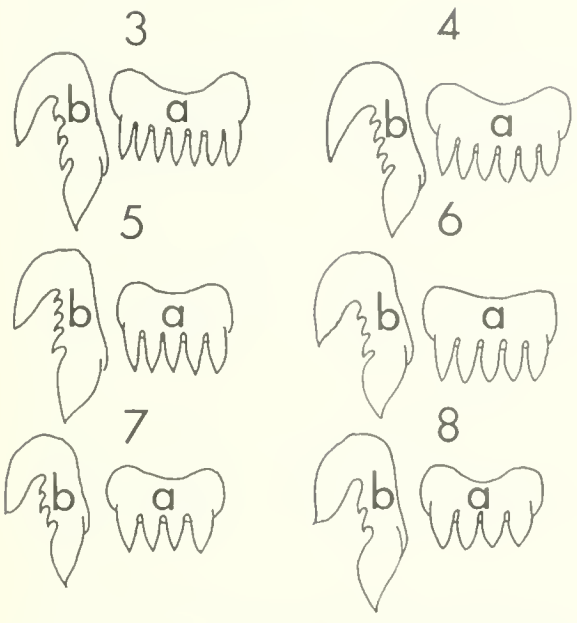
Knobs Coloration	Forward	Recurved	Both	Totals
Red	1 (0.85)	1 (1.52)	1 (0.63)	3
Orange	4 (5.96)	13 (10.66)	4 (4.39)	21
Yellow	4 (6.52)	13 (11.67)	6 (4.81)	23
Pale Yellow	10 (5.67)	7 (10.15)	3 (4.18)	20
Totals	19	34	14	67

TABLE 3. *Contingency Table using the Chi-square "goodness of fit" test for the Null Hypothesis that the two variables, Tumidity and Aperture Coloration, are independent of each other. Expected frequencies are listed in parenthesis next to observed frequencies.* $\chi^2 = 11.71$, *d.f. = 3, at 0.05 confidence level.*

Tumidity Coloration	Present	Absent	Totals
Red	2 (1.34)	1 (1.66)	3
Orange	10 (9.40)	11 (11.60)	21
Yellow	15 (10.30)	8 (12.70)	23
Pale Yellow	3 (8.96)	17 (11.04)	20
Totals	30	37	67

TABLE 4. *Chi-square "goodnes of fit" test for Normality on continuous data, using the Null Hypothesis that the data fits the model Y-N (1.21005, 0.000962681).* $\chi^2 = 7.65$, *d.f. = 7, 0.05 confidence level.*

Class	Class Interval	Observed	Expected
1	0.00 - 1.13	1	0.27
2	1.13 - 1.15	0	1.31
3	1.15 - 1.17	2	4.55
4	1.17 - 1.19	12	10.27
5	1.19 - 1.21	19	15.75
6	1.21 - 1.23	16	16.23
7	1.23 - 1.25	11	11.28
8	1.25 - 1.27	3	5.27
9	1.27 - 1.29	2	1.65
10	1.29 - <	1	0.40
Totals		67	66.97



FIGS. 3 to 8. *Examples of observed variation in radular of* Busycon. *Rachidian tooth* **(a)** *and lateral* **(b)** *teeth; individuals 42*(3), *53*(4), *54*(5), *52*(6), *44*(7) *and 49*(8).

(1948). Variation in the ratio of overall length to aperture length compared to the variation Magalhaes (1948) measured in spire height (Fig. 2).

Although the zymograms produced clearly discernible banding patterns, all of the six enzymes analyzed (N = 67) were monomorphic. Intraspecific monomorphism in electrophoretic banding patterns seems to be typical throughout the *Busycon* genus, based on preliminary data (Jerry Harasewyzh, personal communication).

DISCUSSION

The purpose of this study was to determine which genetic and morphological differences within the local *Busycon* could be identified and to relate such variation to the taxonomy of the genus. The sample exhibited interpopulation normality while displaying characteristics attributed to two different taxa, *Busycon carica* and *B. eliceans*. These findings led to questions involving the validity of these taxa.

Hollister (1958) separated *B. carica* from a dextral sympatric species, *B. eliceans*, in the adult form by the presence of a tumid ridge that runs across the back of the siphonal canal and a more rugged and knobbed shell in the latter. More recently, Abbott (1974) has reassigned *B. eliceans* as a subspecies under *B. carica* using tumidity, knobbiness and aperture coloration for distinction. He has listed *B. carica* as having no tumidity, low knobs and yellow-orange to red aperture coloration; while the subspecies *eliceans* has a tumidity, rugged knobbed shoulders and a white aperture with yellow and brown suffusions (this coloration corresponds to our pale yellow color designation). In the sample studied, no correlation between the presence of a tumid ridge and the direction of knobbiness was observed, and the colorations corresponding to the presence of a tumidity were not those listed in the literature. Of the 44.75% of the population that possessed tumidities, 50% had yellow apertures, 33.3% had orange apertures, 10.0% had pale yellow apertures and 6.7% had red apertures.

We detected no polymorphism in the enzymes that we studied; however, it is important to remember that electrophoretic measurements give minimum estimates of variation (Selander, 1976). So, although no evidence of polymorphism was found, it is not possible to draw final conclusions about the inherent genetic variability of the population from this data. However, since the same techniques have been used to examine electrophoretic variation in other marine invertebrates, conclusions can be drawn by comparing our data with the results of previous work. Monomorphism such as we detected is extremely unusual, particularly in marine invertebrates which are among the most variable groups studied, exhibiting 5% to 50% polymorphic loci and 5% to 15% heterozygosity (Selander, 1976). Specific studies on five marine gastropod species showed a 17.5% polymorphic loci and 8.3% heterozygosity in 17 studied loci (Selander, 1976). Therefore our results are a radical departure from previous work on similar groups and are consistent with the hypothesis that we observed a population of a single species, particularly since intraspecific monomorphism of electrophoretic banding patterns seems to be typical of *Busycon* (Jerry Harasewych, personal communication).

A subspecies as defined by Mayr (1963) is "an

aggregate of local populations of a species inhabiting a geographic subdivision of the range of the species and differing taxonomically from other populations of the species" (p. 672). It has been suggested that species be divided into taxonomic subspecies if more than 75% of the individuals can be recognized as belonging to one or the other taxa (Mayr, 1969). In this study the percentage of specimens that could be recognized as being of one or the other defined subspecies (Abbott, 1974) was only 34.3%, not sufficient to support a subspecies division. We are left to conclude that the observed specimens in this particular area represent a population of a single species.

Reasons for the observed variation within this species may be related to environmental adaptation. Vermeij (1978) identifies factors that contribute to the production of morphological variation in gastropods. Calcification efficiencies, predation pressures, and lack of certain substrate constraints may induce greater morphological diversity toward the southern end of the species range, accounting for increased thickness and knobbiness of southern shells (Vermeij, 1978).

Clinal variation, often used to classify populations within a species (Mayr, 1970), could also explain the morphological variation observed in *B. carica;* however, the word cline refers to a specific character (such as knobbiness), and a species may contain many clines. So although useful as a component of species structure, the character of the word makes it undesirable as a taxonomic divider.

The description of a species should be extensive enough to include the variations in the different parts of its range (Pulley, 1959). In the population we observed there were no indications that its variation necessitates the separation of individuals into either two separate species or subspecies. Therefore we conclude that the population in Wassaw Sound, while including individuals whose characteristics might classify them as either *B. carica* or *B. eliceans,* is a single population and that the subspecies name *eliceans* is unnecessary in the taxonomy of the *Busycon* from this locale.

ACKNOWLEDGMENTS

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THE GASTROPODS, *CALLIOSTOMA ORION* DALL, 1889 (TROCHIDAE) AND *HELIACUS (GYRISCUS) WORSFOLDI* N. SP. (ARCHITECTONICIDAE), FROM THE BAHAMA ISLANDS

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ABSTRACT

Heliacus (Gyriscus) worsfoldi *n. sp., is described from the northwestern Bahamas.* Calliostoma orion *Dall, 1889, is redescribed and the radula and jaws are illustrated by SEM micrographs.* Calliostoma orion *lives in and feeds upon the tube sponge,* Spinosella vaginalis. Heliacus worsfoldi, *the first record of the subgenus* Gyriscus *in the western Atlantic, is associated with a species of* Zoanthus *or* Parazoanthus.

The use of SCUBA equipment by shell collectors has opened an immense area of heretofore inaccessible ocean bottom for examination. This is especially true of the deep fore-reef zone of coral reef tracts such as occur in the Bahama Islands. Numerous specimens of gastropods collected near Freeport, Grand Bahama Island, were loaned to me for identification by Mr. Jack Worsfold. Among these specimens are some representing two species with unusual biological associations.

Type-specimens are deposited in the collections of the U. S. National Museum of Natural History, Washington, D.C., the Academy of Natural Sciences, Philadelphia, Pennsylvania, and the Florida Department of Natural Re-

sources, Marine Research Laboratory, St. Petersburg, Florida, abbreviated USNM, ANSP, and FSBC I respectively. Additional specimens are in the personal collections of Messrs. Jack Worsfold and Bob Quigley, Freeport, Grand Bahama Island.

Family Trochidae Rafinesque, 1815
Genus *Calliostoma* Swainson, 1840

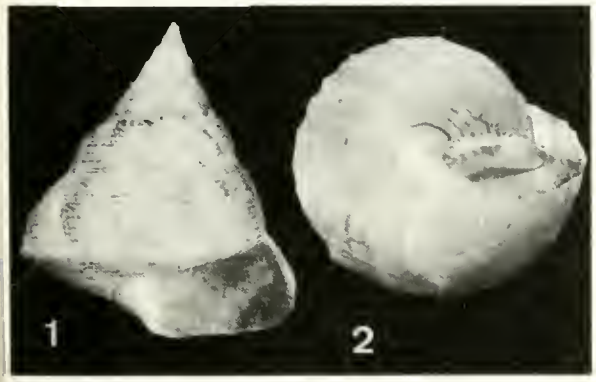
Calliostoma orion Dall, 1889

Figures 1–13

Calliostoma orion Dall, 1889a: 367, pl. 28, fig. 2; 1889b: 162.–Pilsbry, 1889: 383, pl. 48, fig. 18.–Johnson, 1934: 70.–Clench and Turner, 1960: 54, pl. 35, figs. 1, 2.

Description–Shell medium in size, height to about 16 mm, turbinate, imperforate, delicately sculptured by numerous spiral rows of small beads, teleoconch whorls 8–8½; color straw or bone white, often with nebulous areas of light-brown, always with fine, spiral brown lines. Protoconch small, white, 1½ whorls. Early teleoconch whorls flat-sided, last 3 distinctly convex. Spiral sculpture of 20–26 fine cords ornamented by small, sharp, spirally elongate tubercles; cords generally alternate in size. Base almost flat, sculptured by 28–40 smooth spiral cords, generally every fourth larger and colored brown; cords made somewhat undulate by irregular growth lines. Aperture subquadrate; outer lip thin, simple; columella short, thick, straight, white. Operculum thin, multispiral, light amber in color.

Radula typically calliostomatine (Figures 3, 4).



FIGS. 1 *and* 2. Calliostoma orion *Dall, 1889.* **1**, *Apertural view, USNM 784595, 14.8 mm high.* **2**, *Basal view of same specimen.*

Rachidian slender, base pyriform, with long, slender, finely denticulate cusp. Laterals 5; bases pyriform, becoming rhombic on distal 2 (Figure 5); cusps long, slender, becoming very slender on outer laterals, finely denticulate on both sides. Marginals numerous, about 25–30 per half-row; inner marginal large, massive, usually with 6–8 large, strong teeth on proximal margin of tip, finely denticulate on distal margin, with prominent buttress opposite toothed margin (Figure 6); succeeding inner marginals of similar, although less massive, structure without buttress (Figures 4, 6, 7); outer marginals very slender, whisker-like, with fine teeth along both sides of tip, occasionally smooth.

Jaws chitinous, subrectangular, rounded anteriorly and posteriorly, fringed anteriorly (Figures 10, 11). Two major plates joined dorsally by pair of smaller, elongate, corrugated plates (Figures 9, 10). Outer surface of jaws comprised of small, elongate, hexagonal or diamond-shaped scales (Figure 12); inner surface vaguely reflecting outer texture (Figure 13).

Holotype–USNM 214272. Height 4.5 mm; maximum diameter 4.2 mm.

Type-locality–BLAKE station, off Havana, Cuba, 146 m.

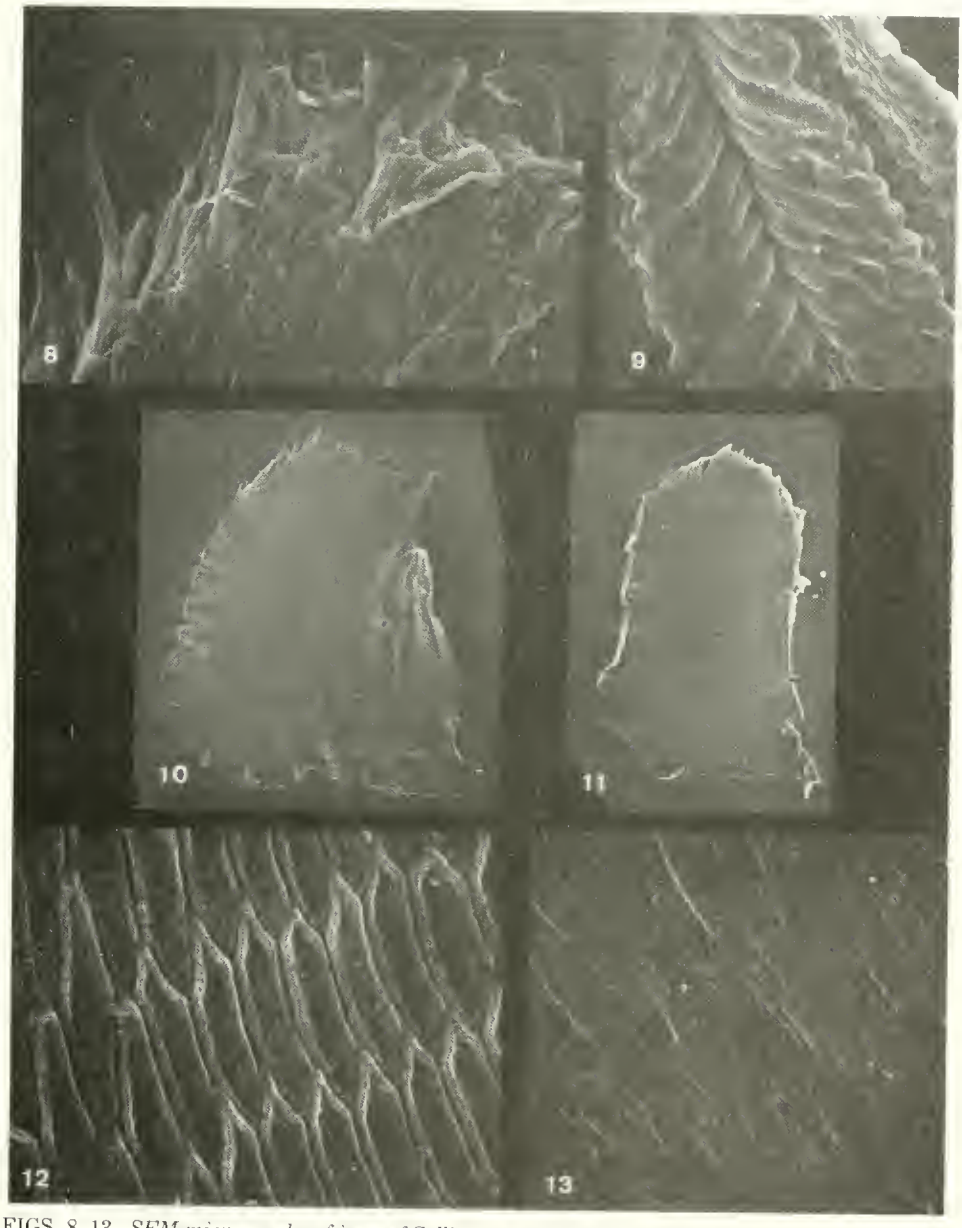
Material examined–BLAKE station, off Havana, Cuba, 146 m; 1 spec., USNM 214272 (Holotype).–Off Tamarind, Lucaya, Grand Bahama Island, Bahamas, on sponge, 15–43 m, J. Worsfold collector; 1 spec., USNM 784595; 1 spec., USNM 784597; 2 spec., ANSP 353315; 1 spec., FSBC I 22163; 1 spec., FSBC I 23777.–Little San Salvador, Bahamas, on sponge, 34 m, J. Tyler collector; 1 spec., USNM 706809.–Providencia Island, Colombia, N. A. Roberts, leg.; 1 spec., ANSP 316567.

Distribution–Known from the eastern and northwestern Bahamas, northern Cuba, and the western Caribbean off Nicaragua, at depths of 15–43 m and 146 m.

Remarks–Until now *Calliostoma orion* has been known from only two shells: the holotype, a juvenile, collected from 146 m off Havana; and a second specimen found at Arenas de la Chorrera in sand dredged from 5–27 m off Sante Fe, Cuba (Clench and Turner, 1960). Both speci-

FIGS. 3–7. *SEM micrographs of radula of* Calliostoma orion *Dall, 1889 (FSBC I 22163).* **3**, *Composite micrograph of radula; 75×.* **4**, *Segment showing laterals and marginals; note denticulation of proximal and distal edges of marginals; 300×.* **5**, *Detail of outer two laterals; apparent fusion of several teeth is an artifact of mounting; 412×.* **6**, *Detail of tip of first inner marginal showing heavy buttress; 658×.* **7**, *Marginal from middle of marginal half-row; 600×.*

mens are bone white in color with the characteristic spiral brown lines very faint. The specimens from Providencia and Little San Salvador Island are also albinistic. However, all specimens examined from Grand Bahama Island are rather richly colored, with brown clouds



FIGS. 8–13. *SEM micrographs of jaws of* Calliostoma orion *Dall, 1889 (FSBC I 22163).* **8,** *Anterior fringe of left lateral plate; 375×.* **9,** *Surface detail of dorsal connecting plates; 375×.* **10,** *Left lateral plate and two dorsal plates, external surface; 60×.* **11,** *Right lateral plate, internal surface; 60×.* **12,** *Lateral plate external surface microsculpture of elongate hexagonal and tetragonal scales; 150×.* **13,** *Lateral plate internal surface microsculpture; 150×.*

superimposed on a straw-colored background, and numerous, distinct brown spiral lines.

In outline, *Calliostoma orion* is extremely similar to *C. marionae* Dall, 1906. The upper whorls are flat-sided, forming an evenly conical spire, but the last 2 or 3 whorls are convex, with the base remaining almost flat throughout. The whorl periphery becomes less angular as growth

progresses. *Calliostoma orion* also differs from *C. marionae* in having beaded sculpture and no umbilicus, as well as being considerably smaller. The very small, sharply-pointed beads on the upper part of the whorls and the shape of the shell immediately separate *C. orion* from other imperforate species, such as *C. euglyptum* (A. Adams, 1854) and *C. sarcodum* Dall, 1927, with which it may be confused.

The radula and jaws are very similar to those described and illustrated for the subgenus *Calliostoma* as restricted by Clench and Turner (1960). In this subgenus there are five marginals with long, slender cusps, a massive inner marginal followed by a number of teeth of less massive but similar structure, and an outer series of very slender marginals. The radula of *C. orion* differs primarily in the shape of the first marginal tooth, especially the buttressed tip and slender rhachis which are more similar to those in the subgenera *Kombologion* Clench and Turner, 1960, and *Elmerlinia* Clench and Turner, 1960. Until radulae of more species of *Calliostoma* are examined using SEM, I refrain from assigning *C. orion* to a subgenus.

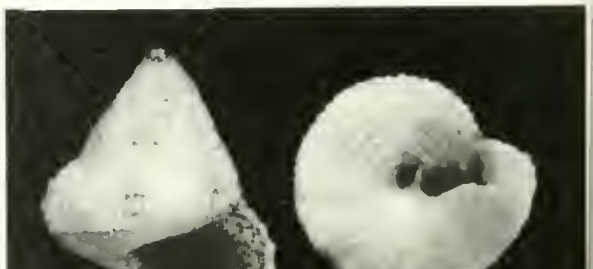
This species, as far as is known, occurs only on deep reefs of the northern and western Caribbean islands. It is not uncommon in depths from 15 to 43 m (50–140 ft) and is always found in the tube sponge, *Spinosella vaginalis* (Lamarck, 1814), in the Bahamas (J. Worsfold, personal communication). A number of recent papers have documented the feeding of *Calliostoma* species on coelenterates (Lang, 1970; Salvini-Plawen, 1972; Francis, 1973; Miller, 1973; Perron, 1975; Perron and Turner, 1978), bryozoans (Perron, 1975), and dead animal flesh (Keen, 1975; Perron, 1975), in addition to the herbivorous or detrital diets previously thought characteristic of all trochids. An examination of the contents of the intestine of a specimen of *C. orion* revealed numerous spicules of *Spinosella vaginalis* (straight oxeas), cellular material of indeterminate origin, and small calcareous fragments. In view of the previous observations of opportunistic feeding of *Calliostoma* spp. and the presence of sponge spicules in the fecal material of *C. orion*, it is probable that this species does in fact feed on *Spinosella*, the first such observation for *Calliostoma*.

Family Architectonicidae Gray, 1850
Genus *Heliacus* Orbigny, 1842
Subgenus *Gyriscus* Tiberi, 1867
Heliacus (Gyriscus) worsfoldi n. sp.

Figures 14, 15

Description–Shell small, height to 7.3 mm, solid, turbinate, umbilicate, with high spire; whorls rounded, sculptured by spiral rows of beads; color of shell whitish to light mauve, with 8–10 axially elongate blotches of light-brown around periphery; umbilicus purplish brown within, columella stained with purplish brown. Protoconch anastrophic, prominent, glassy, brown, 0.84 mm in greatest diameter. Teleoconch whorls 4, subtubular, with 5 or 6 beaded, spiral cords above periphery and 8 or 9 (rarely 7 or 10) on base; axial sculpture of low, rounded, flexuous threads. Umbilicus narrow, about 15% of greatest shell diameter, lightly wrinkled by growth lines. Aperture circular; outer lip thin, crenulated by external sculpture; columella concave, lip slightly reflected, smooth. Operculum thin, circular, multispiral, light-brown in color; external surface concave, with concentric overlapping foliations; nucleus central; inner side with prominent, clockwise-spiraled central plug.

A color slide (*ex* J. Worsfold) of the ventral view of a specimen with animal expanded shows the foot deeply bifid anteriorly and broadly



FIGS. 14 *and* 15. Heliacus (Gyriscus) worsfoldi *Quinn, n. sp.* 14, *Apertural view of holotype, USNM 784593, 7.3 mm high.* 15, *Basal view of same specimen.*

rounded posteriorly. Color of foot light mauve, with numerous spots of opaque white. Tentacles long, tapering gradually to rather bluntly rounded tips; color light mauve, with zig-zag markings of darker purple. Radula not preserved.

Holotype–USNM 784593. Height 7.3 mm; maximum diameter 6.2 mm.

Type-locality–Off Settlement Point, Grand Bahama Island, 12.2 m, J. Worsfold and B. Quigley, collectors.

Paratypes–USNM 784596, 2 spec.; FSBC I 23778, 2 spec.; ANSP 353241; 2 spec.; J. Worsfold and B. Quigley collections, 43 spec.; all specimens with same data as holotype.

Remarks–Heliacus worsfoldi is the third known species of the subgenus *Gyriscus,* which was established by Tiberi (1867) for *Gyriscus jeffreysianus* Tiberi, 1867, described from off Sardinia, Italy. One of the three syntypes of *H. jeffreysianus* is in the USNM and has been redescribed by Merrill (1970). Specimens of the new species are superficially very similar to those of *H. jeffreysianus* but are smaller, have a smaller protoconch [range 0.810–0.875 mm, $\bar{x}$ = 0.84 mm for *H. worsfoldi;* 0.95 mm for *H. jeffreysianus* (Merrill, 1970)], have fewer primary spiral cords (5 or 6, not 7), lack intercalary secondary spiral threads, have a proportionally narrower umbilicus *(H. worsfoldi:* 15% of maximum shell diameter; *H. jeffreysianus:* 20%), and are a different color. Powell (1965) described *Gyriscus asteleformis* from off the northern tip of North Island, New Zealand, from a depth of 50 fathoms. Powell's species differs from *H. worsfoldi* in being larger, proportionally broader, uniformly buff-colored, in having more numerous and more finely beaded spiral cords, and a larger umbilicus.

All of the specimens of *H. worsfoldi* were collected together on a specimen of the antipatharian, *Cirripathes* sp., which was largely enrusted by a species of *Zoanthus* or *Parazoanthus.* Previously, architectonicids have been observed in association with scleractinian corals (Robertson, Scheltema and Adams, 1970) and the zoanthiniarians *Zoanthus* and *Palythoa* (Robertson, 1967; Marche-Marchad, 1969), and Powell (1965) reported *Heliacus (Gyriscus) asteleformis* from the cavity of a sponge. Robertson (1981) has recently reviewed the gastropods symbiotic with zoanthiniarians, of which assemblage *Heliacus* was a major constituent. It is therefore probable that *H. worsfoldi* is also symbiotic with the zoanthid, although the possibility of an association with antipatharians cannot yet be dismissed.

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I am grateful to Mr. Jack Worsfold who brought the two species to my attention and who kindly donated the type material. Sally D. Kaicher made the excellent photographs, and W. G. Lyons and D. K. Camp reviewed the manuscript. Lana Tester provided SEM services.

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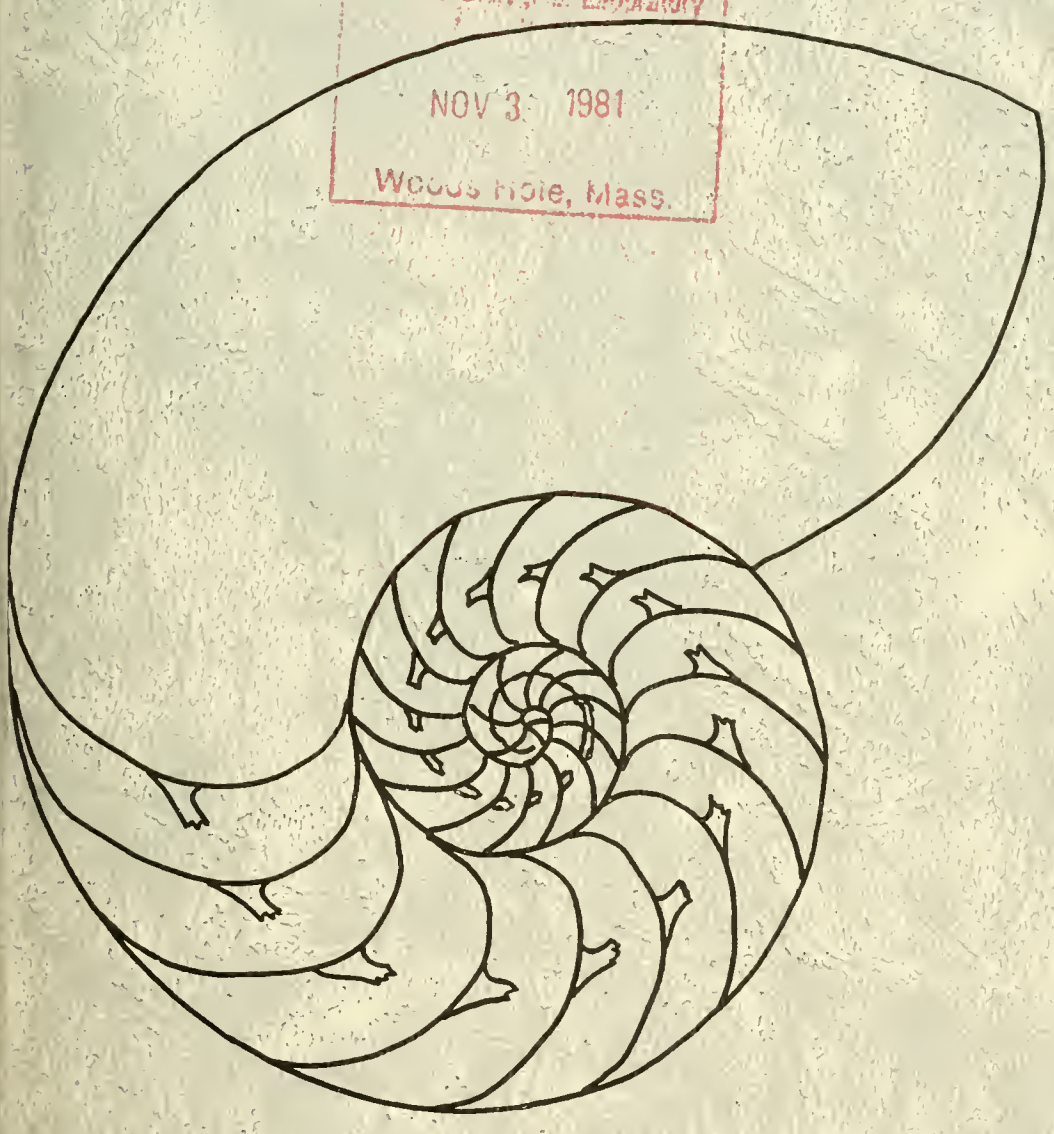

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MALACOLOGICAL JOURNEY INTO CUBA, 1980

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The Smithsonian and the Academia de Ciencias de Cuba have joined in an exchange program whereby scientists of both institutions may visit the other and conduct research of mutual interest. Several Smithsonian scientists have done this: Raymond Manning and Meredith Jones (Crustacea and Worms), were early participants (1978). Storrs Olson (Birds) traveled to Oriente Province in October 1980 for a joint ornithological expedition; Porter Kier (Fossil Echinoids) visited during late October 1980 and worked in the Geological Institute collections. Early in 1980 I indicated an interest in participating in the exchange program. It was my feeling that a Smithsonian malacologist should visit Cuba, renew acquaintances with old colleagues, meet new ones, and begin to reestablish what was a very active program of cooperative research.[1] Another very important reason for wanting to visit Cuba was the hope of examining old and new collections of research interest and to carry out field work. As it turned out I accomplished all but some hoped-for field work in Pinar del Rio, that mecca for Cuban land Mollusca. I boarded the plane at National Airport, left Washington at 7:30 a.m. on November 10, 1980, and arrived in Toronto, Canada, my Cuban disembarkation point, at 10:30 a.m. The Havana bound *Air Canada* flight left Toronto at noon and arrived at 3:30 p.m.

Upon arrival in Havana the passengers from the *Air Canada* DC-8 were gathered into the terminal to await passport examination, a process which occupied at least an hour. My welcoming party patiently waiting outside the customs shed consisted of Dr. Fernando Gonzalez Bermudez, director of the Instituto De Zoologia, Academia De Ciencias De Cuba, Jose Fernandez Milera, Curator of Mollusks, and others. After warm greetings, and since it was then nearing 5:00 p.m., I was driven into the city to the residence for visiting scientists at no. 212 Prado (now Paseo San Marti) where I was to be housed and fed during my stay.

The residence, once the house of an important official, is beautifully furnished in Spanish motif, replete with marble floors, stairways and statues. Rooms are large, well-furnished and air-conditioned. Three meals a day are served in the large well-attended dining room. While there I met scientists from France, Germany and other Latin American countries, for Cuba has cooperative research agreements with many countries.

On the following morning I was picked up at 9:00 a.m. and driven to the Zoological Institute on the west side of Havana. The road traversed the Malecon, the famous Havana waterfront road that runs from the harbor entrance (Morro Castle) past the entire city proper. As those who have visited Havana already know, the downtown area boasts many large tourist hotels, one of the most prominent being "The Rivera". Upon arriving at the Zoological Institute a meeting was held during which I was introduced to staff concentrating on various malacological problems: Jose Milera, who as I mentioned, is in charge of the Institute's mollusk collections; Jose Espinosa, who is collaborating with Hortensia Sarasua on systematic revisions of Cuban prosobranchs; Isabela Cortes Vico, of the Institute's Department of Terrestrial Ecology, who is working on problems concerning the establishment of an escargot resource utilizing the large land snail, *Zachrysia guanensis castanea;*

[1]For early accounts of Cuban visits see *The Nautilus*, vols. **25**:3 (Webb, 1911); **26**:2 (Henderson, 1912); **26**:99, 111 (Wheeler, 1913); **27**:136 (Henderson, 1914); **28**:4, 49, 133 (Ramsden, 1914, 1915); **31**:41 (Henderson, 1917); **35**:118 (Remington, 1922); **38**:56 (Emery, 1924); **40**:37, 88 (Hand, 1926, 1927), and **62**:78 and **70**:1 (Jacobson, 1949, 1956) [editor].

and Renzo Rodriguez of the same department, who is working on culturing *Polymita* to ensure its preservation in the face of destruction of the habitat and heavy collection pressure. Both of the latter workers are very anxious to contact U.S. scientists who can counsel them or provide references which would help with an understanding of the ecology, dynamics of reproduction, and trophic niches of *Zachrysia* and *Polymita*.[2] At present both are being cultured in the laboratory and have passed through several generations. Various types of commercial food have been accepted by the snails, the most satisfactory results so far having been with *Zachrysia* feeding. The *Polymita* seem to offer more of a problem and Rodriguez is presently performing dissections on the digestive system to determine just what the animals are eating. He certainly would welcome suggestions or references on *Polymita* digestive system anatomy. The address at which they can be reached is: Departamento de Ecologia Terrestre, Instituto de Zoologia, Academia de Ciencias de Cuba, Calle 212 #17A09, esq. 19, Atabey, Municipio Playa, Ciudad Habana, Cuba.

Other malacological research currently being done in Cuba, so far as I could learn, is concerned with matters of public health and disease vectors. I made inquiries about fisheries research, but learned nothing and suggest that information may be obtained by contacting the fisheries directly. I am quite certain that mollusks are being studied by other Cuban governmental institutes such as Oceanology in connection with their research, but learned nothing definite.

After discussing the above, the program was reviewed for the balance of my visit, consisting of laboratory and field studies on Cuban Littorinidae. Also detailed were several extracurricular activities, such as an evening tour of old Havana; an evening at the International Ballet which was then having its season in Havana; dinner at a roof-top restaurant downtown; and a much anticipated visit to the Museo Felipe Poey (which did not take place because the latter was being renovated). My approval of the proposed program was solicited and since the work portion, at least, was what I had hoped for – approval was freely given! There followed a toast (with Cuban banana brandy) to the success of the program. The afternoon was spent reviewing the work of the malacology section and in examining collections.

The next day, November 12, was spent at the malacology section with Milera examining, sorting and naming Cuban Littorinidae. Due to a number of nomenclatorial, distributional and ecological problems, it was agreed that we should co-author a study of that family in Cuba.

As I was interested in tracking down as many of our colleagues as possible, I asked about Alfredo de la Torre, son of Carlos, and was told he works at the Instituto de Geologia. Miguel Jaume, formerly Director of the Museo Felipe Poey, now retired, resides at Calle 42, #3307, Playa 13, Havana, Cuba. He visited me one day at the Institute, is a hearty 73, and was most interested in hearing about and being remembered to his colleagues in the U.S. I am sure he would welcome letters directed to the above address. He is busily engaged in a large bibliographic study on Cuban mollusks.

Field work with Milera, Renzo and a driver, occupied four of the six full days I spent in Cuba. On Thursday, November 13, we traveled via Matanzas to Cardenas, about 150 km east of Havana. There we spent two days completing 15 stations around the Varadero peninsula. Milera, who is an excellent field man, took me to habitats where the maximum number of *Littorina* species would be found. Inclement weather and higher than normal tides seemed to have stimulated some of the *Littorina* to seek "higher ground", such as *L. nebulosa*, which we found to be clustered near the tops of pilings under estuarine conditions. On occasion there would be 100 or more on the top of a single piling, more, claimed Milera, than he had ever noted previously! While near Varadero we collected on the shore near *Xanadu*, former du-Pont Estate, which has been maintained in beautiful condition. The house is now a very elaborate restaurant.

[illegible] Habits of A Cuban Snail, [illegible] A. E. Andrews, 1932, vol. 46, pp. 22–[illegible]

Littorina ziczac, *L. angustior*, *L. lineolata*, *Tectarius muricatus*, *Nodilittorina tuberculata*, and *Echininus nodulosus* all were collected on hard reef substrate, the latter three species often being found at highest shore levels. *Littorina mespillum*, the brown-spotted form, was found in rocky tide pools (a first for me). *Littorina meleagris* was collected at lowest tide line, and *L. angulifera* was rare on mangrove and sea walls. In all, I collected 10 species of Littorinidae on the trip. Two more are known to live in Cuba, the possibly introduced *Littorina flava*, which lives only in the vicinity of Cienfuegos, and *Littorina tessellata*, also an inhabitant of the south coast.

On Saturday, November 15, we traveled to the vicinity of Guira de Melena on the south coast of Cuba where we again collected *Littorina nebulosa* and *Melampus coffeus* both of which were living in great profusion in mangrove and clustered on pilings at Playa Cajio. There were many *Truncatella* in the litter. Attempts to collect at the port of Batabano were largely thwarted by high winds and rain.

On Sunday, November 16, 1980, having evidenced interest in seeing Hemingway's home, I was taken there by Milera and party. The Hemingway estate is located in a suburb of Havana, in the town of San Francisco de Paula, overlooking the city. It is kept as a museum with ground, furniture and contents as they were when the author and his wife lived there. We collected some land snails on the grounds. From there we traveled to nearby Cojimar, a little fishing village that inspired Hemingway to write "The Old Man and the Sea". Collections were made there also (it was there that *L. meleagris* was found plentifully at low tide). The Cubans seem devoted to Hemingway, who made his home there for many years.

While I may have had vague concerns about traveling to Cuba, by the time I had to leave, these had vanished. As those of you who have been there know, the country is a malacological paradise at least for marine and land mollusks. For those unfamiliar with Cuba, I recommend (to U.S. naturalists at least) they read Thomas Barbour's 1945 book, "A Naturalist in Cuba". It relates a great deal about the fauna and flora, and gives one a taste for the island. As a member of our malacological "fraternity" I felt I was genuinely accepted there, and left feeling that we have reestablished some of the old cooperative research interest with the Cubans, and that I accomplished much that I had hoped in going there.

In many ways Cuba's contact with much of the rest of the malacological world—certainly ours—was largely severed 25 years ago. That means they have to catch up on much recent literature. For instance, Milera's laboratory lacks most of *Johnsonia*, *Occasional Papers on Mollusks*, *The Nautilus*, *Malacologia*, *The Veliger*, etc. They do not have Abbott's second edition of "American Seashells". I have obtained Abbott's book and have sent it to them and he has donated "American Malacologists" and the Supplement. We are sending our reprints. Our International Exchange Service will supply quite a few volumes of the *The Nautilus* that remain from a number Abbott gave the exchange two years ago. Cuban malacologists wish to reestablish contact with their U.S. colleagues and to exchange literature with them. I know Jose Fernandez Milera and his colleagues would like to hear from other malacologists. His address is: Departamento de Malacologia, Instituto de Zoologia, Academia de Ciencias de Cuba, Calle 212 #17A09, Esq. 19, Atabey, Municipio Playa, Ciudad Habana, Cuba. It is my understanding that mail, so directed, will now go through safely, if not rapidly. Milera tells me he would be delighted to exchange specimens (prepared and/or preserved as you want them) for literature.

It may be of interest to U.S. malacologists that it is possible for them to visit Cuba, and, in fact, I was encouraged to spread this good news to my colleagues. A Cuban Visa may now be legally obtained by U.S. citizens and travel is by way of Canada or Mexico via the airlines of those countries. Your travel agent should be able to provide the necessary information. Staff of the Instituto de Zoologia, and especially Milera, recommended your contacting them if you would like to have their guidance and help in collecting and studying Cuban mollusks.

I departed Cuba on *Air Canada* at 5:00 p.m., Monday, November 17. It was 32°F and snowing when I arrived in Toronto and I was afraid the many living mollusks, for which I had an import license, would die of the cold shock. They survived, however, and following a night in Toronto I continued on to Washington the next day to conclude a fruitful and interesting trip.

POPULATION STRUCTURE AND BIOLOGY OF *LIGUUS* TREE SNAILS ON LIGNUMVITAE KEY, FLORIDA.

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ABSTRACT

Two named color forms of Liguus fasciatus *are native to Lignumvitae Key. The two color forms,* simpsoni *and* lignumvitae *constitute about 90% of the total population. The form* simpsoni *grows larger than* lignumvitae *in the dense hammock, but the opposite is true along the hammock edge. Individuals of both forms from the hammock edge, are significantly larger than individuals of the same form and age class from the central portion of the hammock. A population estimate suggests that there are about 28,500 snails on the Key in age classes 2 through 6 years. Three introduced forms of* L. fasciatus; dryas, delicatus, *and* subcrenatus *make up the remainder of the population. About 178 of the Key's 280 acres appears to be suitable* Liguus *habitat. Experiments examining the probability of dispersal via rafting showed that* Liguus *died after short exposures to sea water.*

A great deal of work has been published regarding the taxonomy of tropical tree snails in the genus *Liguus*. Much of the taxonomic work regarding Florida *Liguus*, done by Simpson, Clench, McGinty, and Pilsbry, was summarized by Pilsbry (1946) in his monograph on North American land molluscs. With the exception of a recent paper by Voss (1976), most articles regarding *Liguus* biology have been popularized, presenting interesting but generalized information (Doe, 1937; Jones, 1954; Davidson, 1965). There is still a great deal to be learned regarding various aspects of their biology, but it has become increasingly difficult to find pristine colonies of *Liguus*. Many colonies have been adversely influenced by human activity either through modification of the colonies' composition (by the introduction and establishment of new forms), or the modification of the hammock habitat by lumbering or real estate development. The purpose of this study was to examine the population structure and evaluate the status of the *Liguus* population on Lignumvitae Key. In addition, an effort was made to examine the likelihood that *Liguus* are able to traverse great distances across seas by rafting.

Lignumvitae Key was privately owned and, because of its isolation, was never developed commercially. The Key is now a Florida State Botanical Preserve which can only be reached by boat. It is unique in that the Key's hardwood forest, or hammock, has for the most part remained intact, with some trees well over 500 years in age. The height and diameter of these trees are matched by only a few stands of hammock left on the northern portion of Key Largo. The Key has an elevation of about 5 m making it among the highest in the 200 km long chain of

islands which extend from the southern tip of Florida to within about 130 km of Cuba. In addition to its forest, the Key has a number of fresh water springs.

METHODS

Three study sites were established on the Key, each measuring 25 by 25 m. The first site was located on the east side of the Key about 300 m N.W. of the boat dock. The second site was just north of the main trail near the center of the Key, while the third site was on the west side of the Key, about 350 m N.W. of site 2.

Dead snails were collected in order to determine the areas and degree of mortality. Trees 4" or more in diameter were identified and counted. The age class of a snail was based on how many growing seasons the snail had experienced. An annual growth line appears on the shell of each snail caused by the deposition of new shell at the thickened lip formed the previous year. This interface is marked by a furrow which is often a different color. The annual growth line is quite prominent on most shells and usually can be distinguished easily from lines formed by interrupted growth during the growing season. Measurements of length were made with vernier calipers and rounded to the closest 1/10 of a mm. These measurements were taken in November after the snails had finished their seasonal growth.

A Lincoln Index was conducted on 4 different occasions at each site to estimate the population density. For each index the snails received a distinctive mark. Individuals in age class 1 (snails in the first growing season) were not included in the recapture study for two reasons: (1) their small size precludes them from being observed and thus recaptured with the same probability as snails which are 2 years or older, and (2) snails in this age class are very fragile and might be subjected to a great deal of damage if included in the study.

To examine the effects of exposure to salt water on *Liguus* two experiments were conducted using 90 snails in age classes 2 to 5 collected on North Key Largo. These snails were divided into 3 color groups of 30 individuals, each of which contained 22 *lineolatus*, 6 *castaneozonatus*, and 2 *elliottensis*. Snails in the first group were allowed to attach to 3 Dogwood branches, 10 to a branch. The branches were placed in a protected lagoon and the response of the snails observed. The branches floated in water about 1 m deep. Snails which fell off the floating branches were retrieved, rinsed with fresh water, and returned to Key Largo. The second group of snails was placed on a piece of plywood and left floating in the same Lagoon (on Plantation Key, Oct. 5, 1978) for 2 hours. The third group served as the control and was placed in a screen covered box on a dock within 4 m of the snails being tested. Both experiments were conducted under calm weather conditions, with only 2 cm ripples caused by light wind. A thin film of sea water covered the upper surface of the plywood board, but at no time were the board or snails submerged.

RESULTS

The plant survey indicated 16 tree species were distributed among the 3 study sites, with 3 species contributing over 60% of the individuals. Table 1 indicates the species composition for each site and the relative frequency of each tree

TABLE 1. List of tree species found in each study site, and the % occurrence of trees with a 4 inch or greater diameter at each site.

Percent Occurrence			Tree Species
# 1	# 2	# 3	
-	-	1.6	*Guaiacum sanctum* Lignumvitae
-	-	3.2	*Thrinax floridana* Thatch Palm
-	-	3.2	*Conocarpus erecta* Buttonwood
-	3.6	-	*Cocos nucifera* Coconut Palm
-	21.8	-	*Swietenia mahogoni* Mahogany
11.3	-	-	*Amyris elemifera* Torchwood
1.6	-	-	*Cyrilla latifolia* Boxwood
8.1	-	-	*Pithecellobium unguis-cati* Cat's Claw
4.8	1.8	-	*Mastichodendron foetidissimum* Mastic
4.8	1.8	4.8	*Pisonio discolor* Blolly
8.1	1.8	6.4	*Metopium toxifeum* Poisonwood
1.6	12.7	9.7	*Piscidia piscipula* Jamaica Dogwood
1.6	1.8	3.2	*Ximenia americana* Hog Plum
16.1	16.4	11.2	*Coccoloba diversifolia* Pigeon Plum
9.7	38.2	22.6	*Bursera simaruba* Gumbo-limbo
34.0	1.8	34.0	*Krugiodendron ferreum* Iron-wood
62	55	62	Total number of trees
11	10	10	Number of tree species per plot

species at a site. Because of the dense canopy, little direct sunlight reaches the hammock floor during the warm wet summer, thus, most of the floor is covered with leaf litter, bare soil or exposed coral rock. Plants in the understory occur near clearings and along trail cuts. Species in the understory associated with the study sites are wild coffee *Psychotria nervosa*, white indigo *Randia aculeata*, crabwood *Gymnanthes lucida*, cheesewood *Morinda royoc*, and white stopper *Eugenia axillaris*.

The average of the 4 Lincoln Indices for each site was determined to be 21, 28, and 25 individuals for sites 1, 2, and 3 respectively, with a pooled average of 24.7 individuals per plot. Thus, based on the size of a plot and the acreage of the island suitable as *Liguus* habitat, it is estimated that there are about 28,500 snails in the 2nd to 6th year age classes on the Island.

A comparison of individuals in the hammock with those at the hammock edge indicated that the length of individuals of the same color form and age class inside the hammock was significantly less (t-Test, $P>0.5$) than those from the edge (Table 2). Though there was no statistical difference between the two color forms, individuals of *simpsoni* at all age classes averaged 1 to 3 mm larger than *lignumvitae* in the hammock, but the reverse was true at the hammock edge (Table 2, Fig. 1). Corresponding with the difference in growth in the hammock, compared to the hammock edge, a difference in the distribution of age classes was noted, with the hammock edge having a greater proportion of 2 to 3 year old snails (58 to 65%) than the other por-

TABLE 2. Average size as related to age class and occurrence in the hammock. A t-test was conducted between members of the same age class which occurred in different portions of the hammock.

	Central Hammock				Hammock Edge				
Color Form	Age Class	Average Length mm	S.D.	n	Age Class	Average Length mm	S.D.	n	t Value
lignumv.	1	27.1	0.8	10	1	31.2	1.7	10	2.81
lignumv.	2	37.8	2.0	7	2	44.6	3.3	7	4.53
lignumv.	3	43.9	4.2	10	3	49.4	3.0	16	3.66
lignumv.	4	49.1	2.9	11	4	56.7	4.5	8	4.49
lignumv.	5	53.0	2.0	15	5	58.9	-	2	*
lignumv.	6	55.1	3.1	3	6	61.0	-	2	*
simpsoni	1	28.2	1.7	10	1	30.8	1.2	10	2.93
simpsoni	2	38.9	1.9	10	2	41.4	2.2	8	2.34
simpsoni	3	46.0	2.3	13	3	49.7	3.3	12	3.07
simpsoni	4	50.5	2.9	23	4	55.1	2.5	6	3.19
simpsoni	5	54.2	3.1	19	5	57.8	2.1	5	3.95
simpsoni	6	57.7	0.5	3	6	60.2	1.7	5	*

* t test not conducted unless n was ≥ 5.

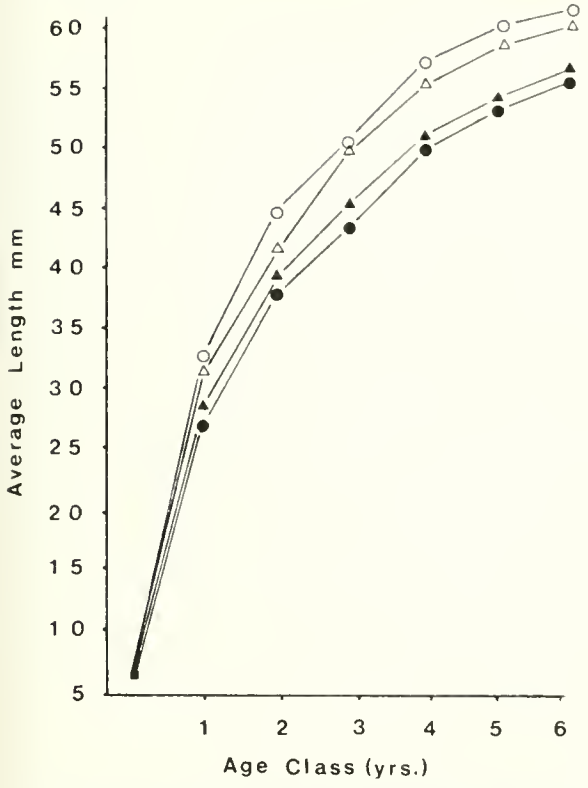

FIG. 1. *Average length of snails from the hammock edge and central portion of the hammock. Open symbols represent snails from the edge of the hammock, closed symbols represent snails from the central portion of the hammock. Triangles* = simpsoni; *circles* = lignumvitae.

tions of the hammock (33 to 41%) as indicated by Figure 2.

Empty shells which were collected at the study sites during October were examined to determine the cause of death. Of the 61 dead *simpsoni* found, 47.0% of the shells were intact and therefore placed into the unknown category, 27.7% of the damaged shells were attributed to mammals and 24.4% to birds. A total of 35 dead *lignumvitae* were found, 31.3% of which were placed in the unknown category, 22.8% were attributed to birds, and 45.7% to mammals. Considering the number of dead shells collected and the present population density, the shells must have represented the accumulation of a number of years. It is possible that damage may have occurred after the death of the snail, which resulted in attributing their death to other causes. From October 1978 to August 1980, 29 additional dead snails were found in the study sites (8 *lignumvitae*, 21 *simpsoni*). All 29 shells represented recent mortalities with 6 *simpsoni* and 2 *lignumvitae* appearing to have been predated, the remainder of the shells were intact.

Observations were made in an effort to examine the likelihood that *Liguus* are able to traverse great distances across seas on floating trees. In the first experiment 10 snails were placed on each of 3 cut Dogwood branches as described in the methods. Within 1 minute after the snails and branches came into contact with sea water, the snails released their grip from the branches and sank to the bottom. Thirty additional snails which were placed on plywood and floated in the lagoon withdrew into their shells upon contact with sea water. All 30 snails died from their 2 hour exposure to a thin film of sea water within 36 hours. No mortality was observed among the control group.

DISCUSSION

Liguus become active in the spring following the first warm rains in April or May. It is at this time that the majority of the eggs deposited in the ground the previous fall begin to hatch. The snails feed almost exclusively on lichens, fungi, and algae which grow on the bark of trees. Although snails may be seen on any species of tree on the Key, they show a marked preference for smooth barked trees such as Jamacian Dogwood, Blolly, and Mastic. *Lysiloma* and Dogwood are two tree species preferred by *Liguus* in south Florida, but of the two only Dogwood occurs throughout the Keys. *Lysiloma* does not occur commonly any further south than Plantation Key, about 15 Km northeast of Lignumvitae Key.

During the course of the field work, five named color forms of *L. fasciatus* were found on the Key. The two endemic forms, *simpsoni* and *lignumvitae*, constitute about 90% or more of the *Liguus* population. The remainder of the population consisted of two forms endemic to adjacent Lower Matecumbe Key, *delicatus* and *suberenatus*, both introduced to Lignumvitae

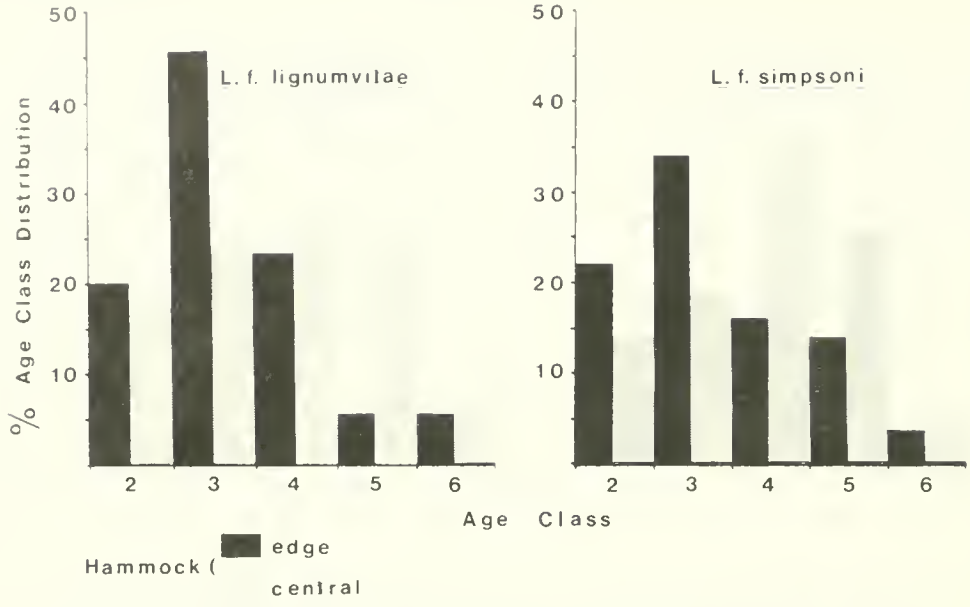

FIG. 2. *Age class distribution varied between the central portion and the edge of the hammock. The number of two-year-old individuals is unexpectedly low, and perhaps related to the unusually dry summer and cold winter on the Key two years ago. Drought effects the hatch and survival of young snails.*

Key around 1955 by C. C. Von Paulsen, according to Mr. A. L. Jones. One specimen of the form *dryas*, also said to be introduced by Von Paulsen, was found.

From April to August the snails remain active and rather mobile, especially during and after a rain. In July and August mating occurs and by early October the snails have come down out of the trees to lay their eggs. The construction of the nest and deposition of eggs requires 1 to 3 days, during which time 5 to 30 eggs will be deposited in the soil near the base of a tree. The eggs may vary in color from light to dark brown, and measure about 7.5×4.0 mm. Weber (1953) and Voss (1976) give additional information regarding nest construction. The time of these events will vary from one Key to the next, as does the behavior of any one individual in a population.

Population Size and Structure

The frequency of thunder storms in the area decreases sharply in October, reducing the movements of the snails. It is at this time that the mark-recapture study was conducted. Four Lincoln indices were conducted at each study site, and the values averaged. The average estimates for the three sites were then pooled giving a value of 24.7 individuals per plot. Thus, based on 178 of the Keys 280 acres being suitable *Liguus* habitat, the population estimate for the Key is about 28,500 individuals in the 2 to 6 year age classes. Frequently as many as eleven first year snails were observed in a study plot, and it is not known how many additional individuals were hidden by foliage. Though no specific data was collected on this age class in the mark-recapture study (for reasons given in the methods) they could have contributed an additional 35 to 45% to the population.

On Lignumvitae Key snails in their first or second growing season continued to grow until November, while older individuals stopped growing in September; for this reason measurements of length were taken in mid-November after all individuals had reached their maximum length. Individuals collected from the hammock edge were significantly larger than those from

the middle of the hammock (Table 2). By plotting size against age class it becomes evident from the slope of the line that the major difference is attributed to growth during the first two seasons (Fig. 1). A difference also exists between the two color forms with the average size of *simpsoni* exceeding that of *lignumvitae* in the central hammock but with the opposite being true along the hammock edge. Thus, it is possible that the two forms represent different biologically adapted types, as indicated by the differential growth rates under similar conditions. It should be noted that physically, conditions on the hammock edge are quite different than in the rest of the hammock. Typically the edge is less humid, has greater light penetration, is exposed to winds, and has an abundance of food on the trees as compared with the inner portions of the hammock on this Key. Although the size difference between the two color forms from the same portion of the hammock was not always statistically significant, this may be due to sample size as the averages show a consistent difference (Fig. 1).

An unexpected difference in age class distribution was found to occur between the hammock and the hammock edge (Fig. 2). In the central hammock the majority of the individuals were of the 4–6 age class, while along the hammock edge the majority were in the 2–3 age class. This difference might be attributed to a higher rate of survival among newly hatched individuals because of greater food availability and less competition from older snails. Mature snails in this area must have a higher mortality rate, or a tendency to move away from the edge into the hammock.

At least three observations on Lignumvitae Key differ sharply from those made by Voss (1976) on two *Liguus* populations on the mainland north of Homestead, and near Miami. Voss indicates that the growth rate of the snails is linear with respect to age. On Lignumvitae Key it is clear that the most rapid growth occurs in the first year and decreases at about the time individuals become sexually mature (3 or 4 years old). Thus, on the Key, shells of 4, 5, and 6 year old snails are not growing in length as fast as 1 year old snails (Fig. 1). Secondly, Voss found that almost all individuals die after apparently breeding only once at the age of 4. He found only 1 individual which was 5 years old, and measured perhaps only 3 individuals greater than 50 mm in length. On Lignumvitae Key about 21% of the *Liguus* population (2–6 yr.) were of the age class 5 and 6, with the vast majority of the individuals 4 years old or older being well over 50 mm (Table 2, Fig. 1). Thus *Liguus* on the Key exhibit a different pattern of growth, live substantially longer (which results in more reproductive attempts), and grow considerably larger than those which Voss examined at Timm's and Brickell Hammocks. Voss failed to mention which forms of *fasciatus* he observed and measured during his study. My own observations in Timm's Hammock revealed at least 14 named forms of *fasciatus* to be well established there in 1978. Although some of the observations by Voss differ from the ones reported here, this is to be expected as he was dealing with different forms of *L. fasciatus* living under biological conditions very different than those on Lignumvitae Key.

Sources of Mortality

All of the empty shells on the ground at the start of the study were collected and placed into 1 of 3 categories depending upon the condition of the shell. Of the 96 dead shells found, about 64% were *simpsoni*, with the remainder being *lignumvitae*. The type of damage differed markably between the two color forms, but the significance of this is not clear because it is not known how much of the damage observed occurred after the death of the snail. During the observations made in 1980, 8 *lignumvitae* and 21 *simpsoni* were found dead in the study area, 21 of the shells showed no sign of damage, but individuals of each color form had been attacked by raccoons. The damage caused to a shell by raccoons typically results in the upper portion of the shell being crushed and on occasion tooth holes may be seen on the remaining portion of the shell. Shells damaged by birds usually have a hole punched in the lower 2/3 of the shell, and it is more likely that a portion of the snail remains in the shell than if it were attacked by a raccoon. Shells which were placed in the unknown cate-

gory may have died in any number of ways, but in all cases the shell remained intact. Causes of death in this group might include predation by land crabs of the genus *Coenobita*, carniverous snails, ants, or old age. Although Eisner and Wilson (1970) suggest that body fluids of *fasciatus* may serve to deture attacking ants, I have observed *Liguus* being attacked and killed by the fire ant, *Solonopsis geminata* (Fab.) on 3 occasions. Thus, *Liguus* may be protected from some species of ants, but not all.

Habitat Stability

In a mature hammock, such as Lignumvitae Key, the *Liguus* population is probably relatively stable barring severe climatic conditions or other catastrophic events. A balance appears to have developed in which light intensity and moisture (influenced by canopy density and climatic predictability) interact to influence the rate at which the snails' food regrows after being grazed. This combined with the relative numbers of smooth-barked trees must determine the over-all carrying capacity. An examination of the Dogwood trees on the Key reveals those in the central hammock to be polished or almost so. This condition results from the continual scraping of the radula on the bark of the trees over a great many generations. A tree which has been polished by *Liguus* appears quite different from one which has been recently occupied and merely had the majority of the food eaten off the bark. In hammocks disturbed by fire where the *Liguus* population was sharply decreased, the food regrows rapidly due to increased light and reduced grazing pressure by the snails. During the second and third years following a fire, large individuals are found. These have a high reproductive success such that the density may exceed that reached prior to the fire. As a result of the population increase, the available food is soon consumed. This causes a shortage for most members of the population and results in stunted growth and lower fecundity. In time the lower fecundity and lack of food results in a general decline in the population. Numerous fluctuations may follow as the balance is established between food availability and the density of snails. Based on the mean size of individuals on the Key and the population density, the Lignumvitae Key *Liguus* population is probably oscillating about a point near the present carrying capacity of the island. Thus, this population is probably relatively stable in relationship to the conditions within the hammock as it presently exists on the Key.

Dispersal of *Liguus*

Pilsbry, (1946) stated that "All naturalists who have considered the subject agree that our *Liguus* were derived from Cuban stocks of the polymorphic *L. fasciatus* (Müller), brought to Florida sealed to floating trees and cast ashore by high winds or hurricanes." Although the origin of our *Liguus* may not be in dispute, the means by which they arrived here is by no means clear. The mode by which Pilsbry suggested that *Liguus* arrived in Florida cannot be discounted, but the likelihood of an event such as he described appears to be much lower than one might expect. Aestivating *Liguus* do form a tenacious seal by which they attach themselves to a tree during the winter, but the hurricane season is during the summer and fall while the snails are active and not in aestivation. In addition, the mucus which seals the snail softens and becomes non-adhesive when moistened for extended periods.

To examine the possibility that non-aestivating snails could survive the journey which Pilsbry described, several tests were run. First, it was observed that the density of some trees, such as Lignumvitae and Ironwood, is greater than that of sea water and therefore they do not float. Other tree species, such as Gumbo-limbo, Dogwood, and Poisonwood, barely remain afloat in calm water. Thus, it appears that many species of trees in the hammocks are not suitable as rafts for *Liguus*.

None of the 30 snails on Dogwood branches remained attached for more than a minute after the branches were placed in sea water. The snails placed on a board, which was floated for 2 hours, never came into contact with water greater than 3 mm deep, and were usually out of the water, but moist. Again, the snails withdrew into their shells upon contact with sea water.

but this time the shell remained setting on the flat surface of the board. No individuals exposed to these conditions during the 2 hour test were alive 36 hours later.

This sensitivity to sea water may explain why many of the forms of *Liguus* endemic to the Keys occurred on only one or two Keys, while forms in the Everglades tend to be more widespread. It appears that aestivating or non-aestivating snails have an exceedingly low probability of surviving a 130 Km trip in a hurricane to reach the southern-most portion of Florida.

ACKNOWLEDGMENTS

I wish to thank Mr. Archie Jones and Dr. Barry Roth for reviewing the manuscript, and Dr. Roy Snelling for identifying the ants. I would also like to thank Kevan O'Kane, and Jim Stevenson of the Florida Department of Natural Resources for their cooperation, and Steve Sparks and Kevin Sunderland for assistance. Special thanks to park ranger Ms. Jeanne Parks for all of her assistance and cooperation.

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A NEW SPECIES OF *VOLUTOCORBIS* (VOLUTIDAE) FROM SOMALIA

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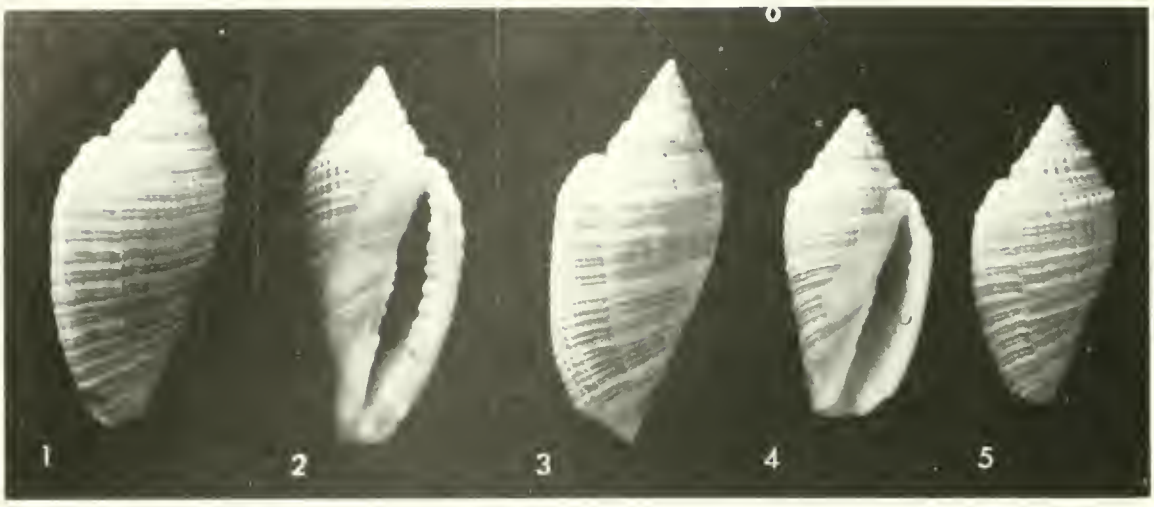
Through the kindness of Dr. Harry G. Lee of Jacksonville, Florida, I received for examination a small series of a species of *Volutocorbis* from Somalia. I recognized immediately that the specimens were unlike any described species of the genus.

With Dr. Lee's permission I am describing this species as new and am pleased to name it in honor of Mrs. Rosavittoria Todaro, from whom Dr. Lee received the specimens. They were collected by Abdulkadir Ma'allin "Javane", from whom Mrs. Todaro obtained the specimens.

Volutocorbis rosavittoriae new species
(Figs. 1–5)

Description: Shell of medium size for genus, heavy, biconic, with the spire sharply conical, about ¼ total length or slightly more. Protoconch mamillate, consisting of about 1⅓ smooth, rounded whorls, the top sometimes obliquely flattened. Postnuclear whorls 5¼–6, first one with axial ribs that become nodulose below suture after first ¼ whorl, with a second spiral row of nodules, separated from the first by a rounded groove; the subsutural row of nodules in later whorls margins a channeled subsutural shelf and may divide and form an upper flattened, less nodulose cord; in later whorls the number of spiral rows of nodules increases with the addition of finer spiral cords, the number of such spiral elements numbering about 45 in paratype #3; the number of axial ribs and riblets



FIGS. 1–5. Volutocorbis rosavittoriae *n. sp.* ×1. 1, *Holotype, dorsal view.* 2, *Holotype, apertural view.* 3, *Paratype no. 1.* 4, *Paratype no. 2.* 5, *Paratype no. 3.*

also increases so that in the same paratype there are 16 riblets in the first postnuclear whorl and about 50 in the last whorl. The last whorl is usually slightly angled at the shoulder by a strong row of pointed nodules, and the entire surface is rendered rough and filelike by the numerous spiral cords and threads made finely nodulose by the crowded axial riblets. The color is pale tan or dark straw-color with white spiral lines or bands. Aperture narrow, pointed at both ends, outer lip broadly thickened inside with 16–22 teeth of various sizes that extend as spiral ridges into the aperture; parietal callus thin, margined above and on lower half, with 7–10 spiral folds on thickened internal lower half, the lowest fold usually strongest; lower part of outer lip flattened near broad, open siphonal canal.

Range: South coast of Somalia from off Kisimayu (Chisimaio) to Brava.

Type locality: Off Kisimayu, southern Somalia.

Measurements (in mm):

	Height	*Width*	*No. of Whorls*
Holotype USNM 784653	50.75	22.9	5¾
Paratype #1 USNM 784654	50.45	22.9	6
Paratype #2 Colln. H. G. Lee	40.25	20.2	5¼
Paratype #3 USNM 784654	39.15	19.4	5¼

Remarks: This species is distinct from other known species of *Volutocorbis* in possessing a stout, thick shell with strong, fine spiral and axial sculpture. In size, general shape, and in the thickness of the outer lip it is closest to *V. semirugata* Rehder and Weaver, 1974, but that species is much smoother, with more strongly shouldered whorls.

Since receiving the four specimens that form the basis of this description, Dr. Lee has learned that this species has been collected in some numbers off Brava on a species of *Xenophora*, probably *pallidula* (Reeve). Of 100 specimens of the latter species 29 had specimens of *Volutocorbis rosavittoriae* affixed to them.

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MONOGRAPHS OF MARINE MOLLUSCA, no. 2. The Family Buccinidae. Part 1: The Genera *Nassaria, Tritonia* and *Neoteron*. 50 pp. By Walter O. Cernohorsky. $7.50. Postage free if order is accompanied by payment. Foreign subscribers please add $1.00 for postage. *American Malacologists, Inc.*, P.O. Box 2255, Melbourne, FL. 32901-0328. U.S.A.

TWO NEW SPECIES OF *ACANTHOCHITONA* FROM THE NEW WORLD (POLYPLACOPHORA: CRYPTOPLACIDAE)

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A systematic revision of the New World Cryptoplacidae has revealed the presence of two new species: *Acanthochitona imperatrix (commanding chiton)* from tropical west America and *Acanthochitona andersoni* from southeast Florida and the Caribbean. Because of the widespread confusion in the literature concerning this family, additional notes on related species have been extracted from the revision to help clarify the taxonomic position of the species involved.

Abbreviations used in the text:

AMNH – American Museum of Natural History, New York.
ANSP – Academy of Natural Sciences of Philadelphia.
DMNH – Delaware Museum of Natural History, Greenville.
MCZ – Museum of Comparative Zoology, Harvard University.
USNM – U.S. Museum of Natural History, Washington, D.C.

Acanthochitona imperatrix new species
(Plate 1a, b, c; Plate 4b)

Description: Holotype 8.9 mm in length, curled. Tegmentum of intermediate valves about twice as wide as long, flattened, not carinate. Beaks prominent. Jugum very wide, flat, smooth, and distinctly raised above the latero-pleural areas. Jugal macresthetes widely spaced, arranged in longitudinal rows, each associated with 0-2 micresthetes. Latero-pleural areas sculptured with numerous teardrop-shaped, close-set pustules, each moderately elevated and concave. Each pustule bears one centrally located macresthete. 0–5 micresthetes (commonly 0) accompany each macresthete and are generally confined to the area anterior to the macresthete. Mucro central and prominent with a concave postmucronal slope. Tegmentum uniformly peach-colored, the jugum lighter. Alternating spots of cream and maroon occur along the posterior borders of the valves and flank the jugum on the holotype.

Apophyses extensive. Slit formula 5–1–2. Articulamentum colored cream, tinged with green towards the beaks.

The dorsum of the girdle is velvety, armed with dense, very minute spicules. These spicules are monomorphic (i.e. – composed of one type of element as opposed to bimorphic, composed of two distinct types of elements), round in cross-section, smooth, and slightly bent. Girdle dorsum peach-colored, ventral side slightly darker. Marginal fringe and sutural tufts well-developed, composed of numerous long, slender spicules.

Type locality: 8 fathoms (14.6 m) off San Diego, California; lat. 24°22′30″ S, long. 110°19′30″ W; taken with tangles on broken shell bottom, April 30, 1888, by the U.S. Fish Commission. *Holotype:* USNM 218762. *Paratypes:* USNM 225346 - Sta. 2826, 9.5 fathoms (17.4 m) off La Paz, Baja California Sur; lat. 24°12′00″ S, long. 109°55′00″ W; taken with oyster dredge on shelly bottom, April 30, 1888, by the U.S. Fish Commission. ANSP 153484 -Seymour Bay, Isla Santa Cruz (Indefatigable Island), Galápagos Islands, by Pinchot Expedition, Pilsbry.

Range: Subtidally to at least 17 m, from southern California to the Galápagos Islands.

Remarks: A. G. Smith and Ferreira (1977) illustrated and described a specimen of this species (ANSP 153484) but did not name it. Their specimen was composed of a head, tail, and three intermediate valves without the girdle. The specimen is labeled as "*A. galapagana* Pils. MS, A. G. Smith TYPE". This name was

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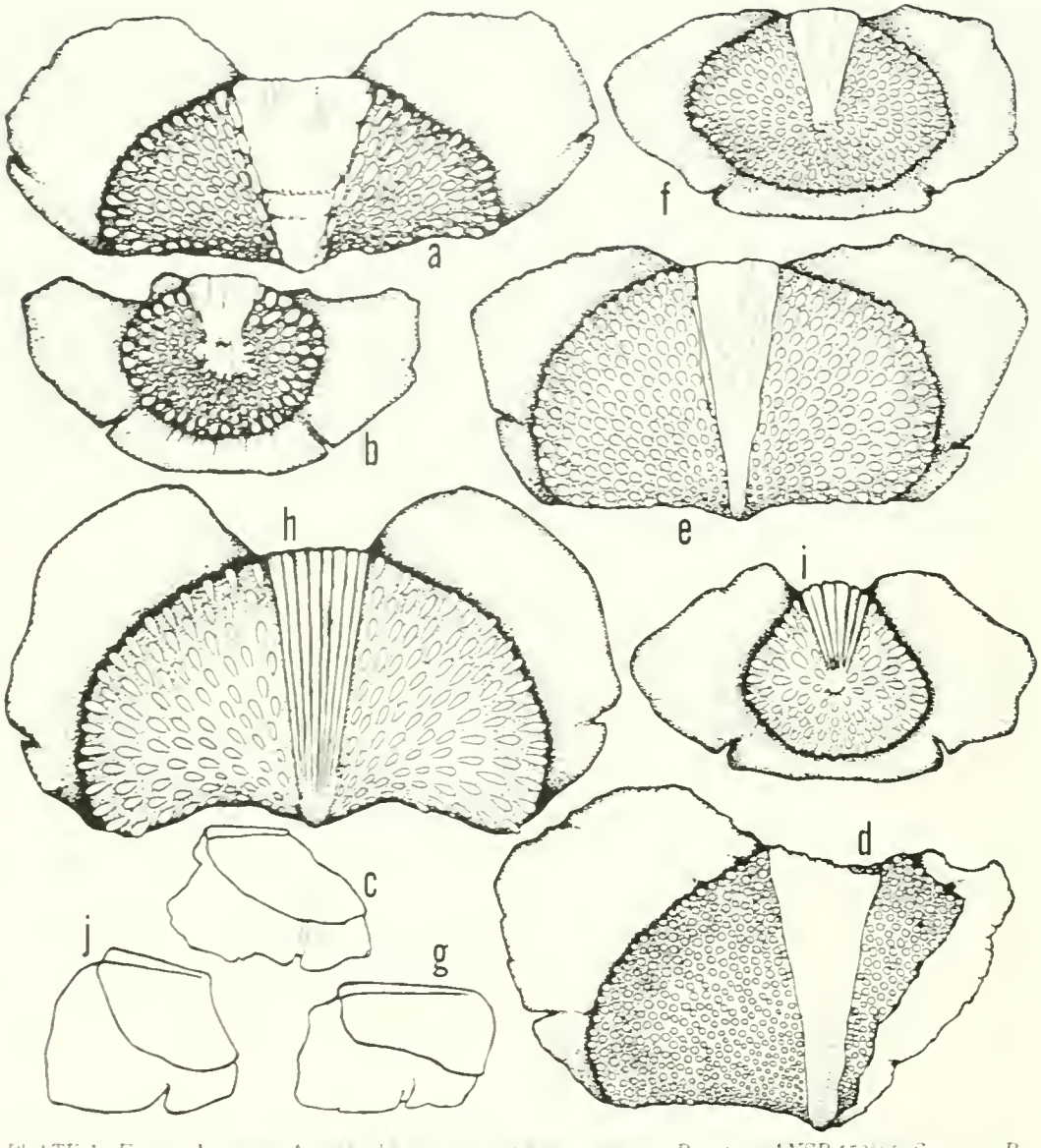

PLATE 1. *Figs.* **a, b,** *and* **c:** Acanthochitona imperatrix *new species, Paratype ANSP 153484, Seymour Bay, Isla Santa Cruz, Galápagos Islands, (a): valve 2 VII, 3.9 mm diameter, (b): valve VIII, 2.8 mm diameter, (c): valve VIII, profile. Fig.* **d:** Acanthochitona communalis *(Rosso, 1826), USNM 218733, Tierra del Fuego, Argentina; valve VII, 5.2 mm diameter. Fig.* **e, f,** *and* **g:** Acanthochitona angelica *Dall, 1919, AMNH 74713, Maria Magdalena Island, Tres Marias Islands, (e): valve VII, 3.5 mm diameter, (f): valve VIII, 2.7 mm diameter, (g): valve VIII, profile. Fig.* **h, i,** *and* **j:** Acanthochitona avicula *(Carpenter, 1864), AMNH 130977, Agua de Chale, Gulf of California, Mexico, (h): valve VII, 3.7 mm diameter, (i): valve VIII, 2.3 mm diameter, (j): valve VIII, profile.*

Dr. Ferreira (written comm.) [illegible] with it. Subsequently I located [illegible] specimens at the U.S. National Museum [illegible] and 218762), the latter of which I designated as holotype.

Acanthochitona imperatrix is one of several species in a New World complex composed of forms characterized by broad, rectangular, intermediate valves bearing teardrop-shaped pustules and a centrally located, prominent

mucro. In addition to *A. imperatrix*, the complex contains *A. angelica* Dall, 1919, *A. avicula* (Carpenter, 1864), *A. communis* (Risso, 1826), and *A. spiculosa* (Reeve, 1847). A second complex, composed of *A. astriger* (Reeve, 1847), *A. exquisita* (Pilsbry, 1893a), *A. hemphilli* (Pilsbry, 1893a) (*rhodea* (Pilsbry, 1893a) is this species), *A. hirudiniformis hirudiniformis* (Sowerby, 1832) (*coquimboensis* (Leloup, 1941a) and *tabogensis* A. G. Smith, 1961, are this species), and *A. hirudiniformis peruviana* (Leloup, 1941a), is differentiated by having long, pentagonal valves, oval to teardrop-shaped pustules, and a low, posteriorly acentric mucro. The third New World complex will be discussed under the following remarks of *Acanthochitona andersoni* new species.

The superspecies that contains *A. imperatrix* antedates the closing of the western Tethys Sea and probably stems from *A. communis* or its immediate ancestor. *Acanthochitona communis* (pl. 1d; pl. 4a) is a widely distributed species throughout the Mediterranean, the eastern Atlantic from Spain to Great Britain and the Azores (Malatesta, 1962), the Cape of Good Hope and the Falkland Islands (Leloup, 1941a), Tierra del Fuego (USNM 218733), and the southern Caribbean (as *A. bonairensis* Kaas, 1972). The dorsal girdle elements of *A. communis* are bimorphic while those of *A. imperatrix* are monomorphic; furthermore, *A. communis* does not possess the very wide, flat, distinctly raised jugum of *A. imperatrix*.

Acanthochitona angelica Dall, 1919, (pl. 1e, f, g; pl. 4e) differs in having bimorphic girdle elements, both of which are bent and striated; those of *A. imperatrix* are straight and smooth. The jugum of *A. angelica* may be longitudinally striated and is never as wide as in *A. imperatrix*. A. G. Smith (1977) inexplicably synonymized *A. angelica* with *A. avicula* despite obvious differences between the two species and *A. angelica* has not been recognized as distinct in recent years (Putnam, 1980, and Kaas and Van Belle, 1980). The dorsum of the girdle of *A. angelica* is velvety, composed of minute spicules, while those of *A. avicula* are coarse and thorn-like. In addition, the pustules of *A. angelica* are never as large and elongated as those of *A. avicula*. A. G. Smith and Ferreira (1977) introduced *A. jacquelinae*, a synonym of *A. angelica*.

Acanthochitona avicula (Carpenter, 1864) (pl. 1h, i, j; pl. 4c, d) differs from *A. imperatrix* in possessing a striated jugum and large, bent, distally striated spicules among the smaller, smooth elements on the dorsum of the girdle. *Acanthochitona avicula* variety *diegoensis* (Pilsbry, 1893b) is a common variant; the lectotype, herein designated, is ANSP 349330 from San Diego, California (pl. 4d).

Acanthochitona spiculosa (Reeve, 1847) (pl. 2a, b, c; pl. 4f, g) from the Caribbean and southeastern U.S. also has a striated jugum and bent dorsal elements. The *A. pygmaea* of Abbott (1954, 1974), Kaas (1972), Warmke and Abbott (1964), Kaas and Van Belle (1980), and others, is *A. spiculosa*. *Acanthochitona pygmaea* (Pilsbry, 1893b) is based upon a juvenile of *A. spiculosa*; the lectotype, herein designated, is ANSP 35783 from Key West, Florida (pl. 4g). The "*spiculosa*" of these same authors (and of most collections) is *A. astriger*, a common West Indian species which has been confused with *A. spiculosa* ever since E. A. Smith (1890) first misidentified his specimens. *Acanthochitona astriger* (pl. 2d; pl. 4h) never possesses a striated jugum and has longer, more pentagonal valves than *A. spiculosa*. The complicated synonymy of these two species will be presented at a later time.

Synonymy:

Acanthochitona species? A. G. Smith and Ferreira, 1977, *Veliger* 20:82, 97, fig. 22.

Acanthochitona andersoni new species

(Plate 2e, f, g; Plate 4i)

Description: Maximum size 12 mm in length. Tegmentum of intermediate valves longer than wide, pentagonal in outline. Beaks prominent. Jugum wide, smooth except for growth lines. Jugal macresthetes widely and irregularly placed, generally absent from the central portion of the jugum. Each macresthete is accompanied by 1–5 micresthetes. Mucro posteriorly acentric, very prominent; postmucronal slope steep and concave. Lateropleural areas sculptured with widely spaced, convex, "D"-shaped pustules which radiate from the beak. Each

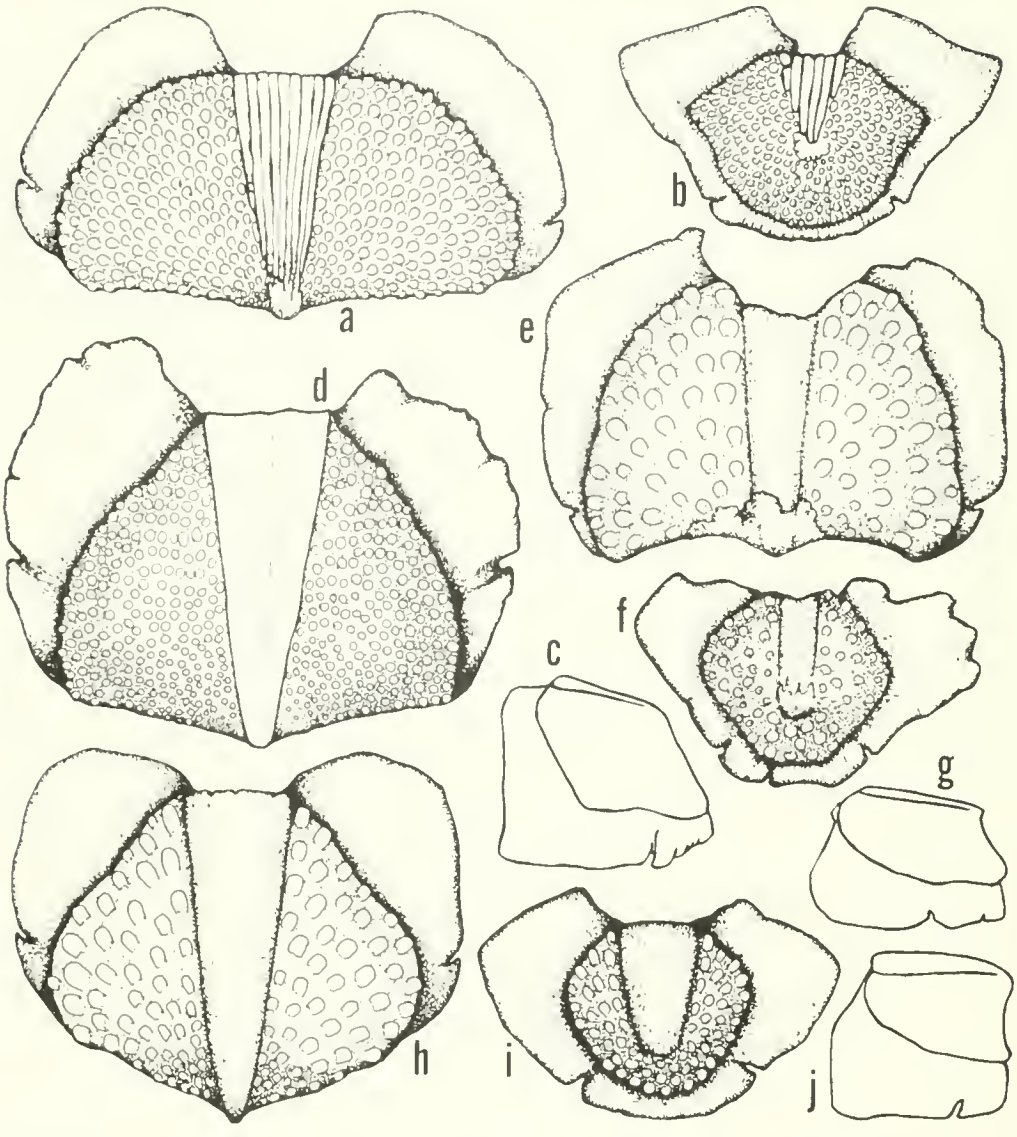

PLATE 2. *Figs.* **a, b,** *and* **c:** Acanthochitona spiculosa *(Reeve, 1847). Watters collection, Windley Key, Florida. (a): valve VII, 2.8 mm diameter. (b): valve VIII, 1.9 mm diameter. (c): valve VIII, profile. Fig.* **d:** Acanthochitona astriger *(Reeve, 1847). Bullock collection, Magueyes Island, La Parguera, Puerto Rico; valve VII, 3.3 mm diameter. Figs.* **e, f,** *and* **g:** Acanthochitona andersoni *new species, Paratype DMNH 95383, Picquet Rocks, Bimini, Bahamas. (e): valve VII, 1.7 mm diameter. (f): valve VIII, 1.4 mm. (g): valve VIII, profile. Figs.* **h, i,** *and* **j:** Acanthochitona arragonites *(Carpenter, 1857), Watters collection, Bahía de Kino, Sonora, Mexico. (h): valve VII, 2.1 mm diameter. (i): valve VIII, 1.8 mm diameter. (j): valve VIII, profile.*

pustule bears one macresthete located towards the prepustular edge. The 2–7 micresthetes per pustule are directed generally to the prepustular slope. Tegmentum mottled brown, yellow, green, or nearly white; pustules may be colored differently from the rest of the tegmentum. One paratype (DMNH 95383) is uniformly blackish-brown with occasional white pustules.

Apophyses moderately extensive. Slit formula 5–1–2, with interslits in some specimens.

Articulamentum translucent white, the color of the tegmentum showing through.

The entire girdle is velvety, armed with dense, bimorphic spicules on the dorsum. Both types are flattened in cross-section, bent, and smooth, but differ in size. Girdle variously colored green, white, dark-brown, tan, or mottled with these colors. Sutural tufts and marginal fringe well-developed but composed of only a few long, stout elements colored translucent white.

Type locality: Sta. 2, rocky cove, south shore of point, 1 km south of Calliaqua, St. Vincent, Lesser Antilles. *Holotype:* ANSP 332171. *Paratypes:* ANSP 220834 - 30 fathoms (54.6 m), on wreck, off Destin, Florida; ANSP 220833 - 30 fathoms (54.6 m), off Boynton Beach, Florida, Bales; Bullock collection - West Summerland Key, Florida; USNM 103424 - Key West, Florida, from U.S. Fish Commission; USNM 181248 - Key West, Florida, April 15–27, 1884; USNM 663398 - Key West, Florida, Weber; MCZ 204125 - Dry Tortugas, Florida, 1940, E. Koto; USNM 735327 - Sta. 52–60, on coral, center of Nicchehabin Reef, East Allen Point, Ascension Bay, Quintana Roo, Mexico; Bredin - Smithson. Inst. Expedition, April 10, 1960, Rehder & Bousfield; USNM 736249 - Sta. 85 & 95, Suliman Point, Ascension Bay, Quintana Roo, Mexico; Bredin - Smithson. Inst. Expedition, April 17 & 19, 1960, Schmitt et al.; USNM 736058 - Ascension Bay, Quintana Roo, Mexico; Bredin - Smithson. Inst. Expedition; Bullock collection - Galeta Point, Canal Zone; ANSP 325808 - 1 mile west of Haulover, North Bimini, Bahamas; ANSP 325864 - 1 mile east of Turtle Rocks, southwest of concrete ship, 18 feet (5.4 m), Bimini, Bahamas, 1957–58, Robertson; DMNH 95383 - 10.6 m on *Strombus gigas*, Picquet Rocks, Bimini, April 17, 1973, Watters; MCZ 238906 - Goat Key, Andros Island, Bahamas, Patterson; MCZ 390 - Tobago Island, Clarke; Bullock collection - St. Jorisbaai, Curaçao.

Range: Subtidally to at least 55 m, from Quintana Roo to southeastern Florida and the Bahamas, the Lesser Antilles, and the Netherlands Antilles.

Remarks: This new species is not uncommon in collections but is often misidentified as other species, particularly as *A. pygmaea* (=*A. spiculosa*) and *A. balesae* Abbott, 1954. It is part of distinct complex containing *A. arragonites* (Carpenter, 1857) and *A. balesae*. The species of this complex are recognized by the vermiform body and convex, "D"-shaped pustules. All other New World *Acanthochitona* have concave, teardrop-shaped or oval pustules.

Acanthochitona andersoni is closely related to *A. arragonites* (pl. 2h, i, j; pl. 4k), its cognate from the eastern Pacific, but can be differentiated by the dorsal girdle elements: in *A. andersoni* they are bimorphic, both types being flattened in cross-section, smooth, and bent, but of two distinct sizes; in *A. arragonites* they are monomorphic, round in cross-section, finely ribbed, and bent.

Acanthochitona balesae (pl. 3a, b, c; pl. 4j) differs from *A. andersoni* in having the dorsal elements monomorphic, flattened in cross-section, strongly ribbed, and bent. The pustules

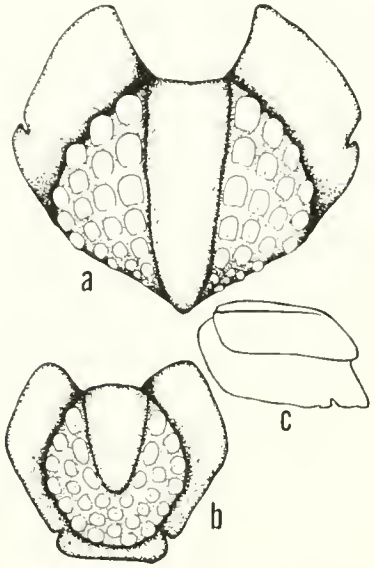

PLATE 3. *Figs.* **a, b,** *and* **c:** Acanthochitona balesae *Abbott, 1954, Bullock collection, Magueyes Island, La Parguera, Puerto Rico. (a): valve III, 1.9 mm diameter. (b): valve VIII, 1.6 mm diameter. (c): valve VIII, profile.*

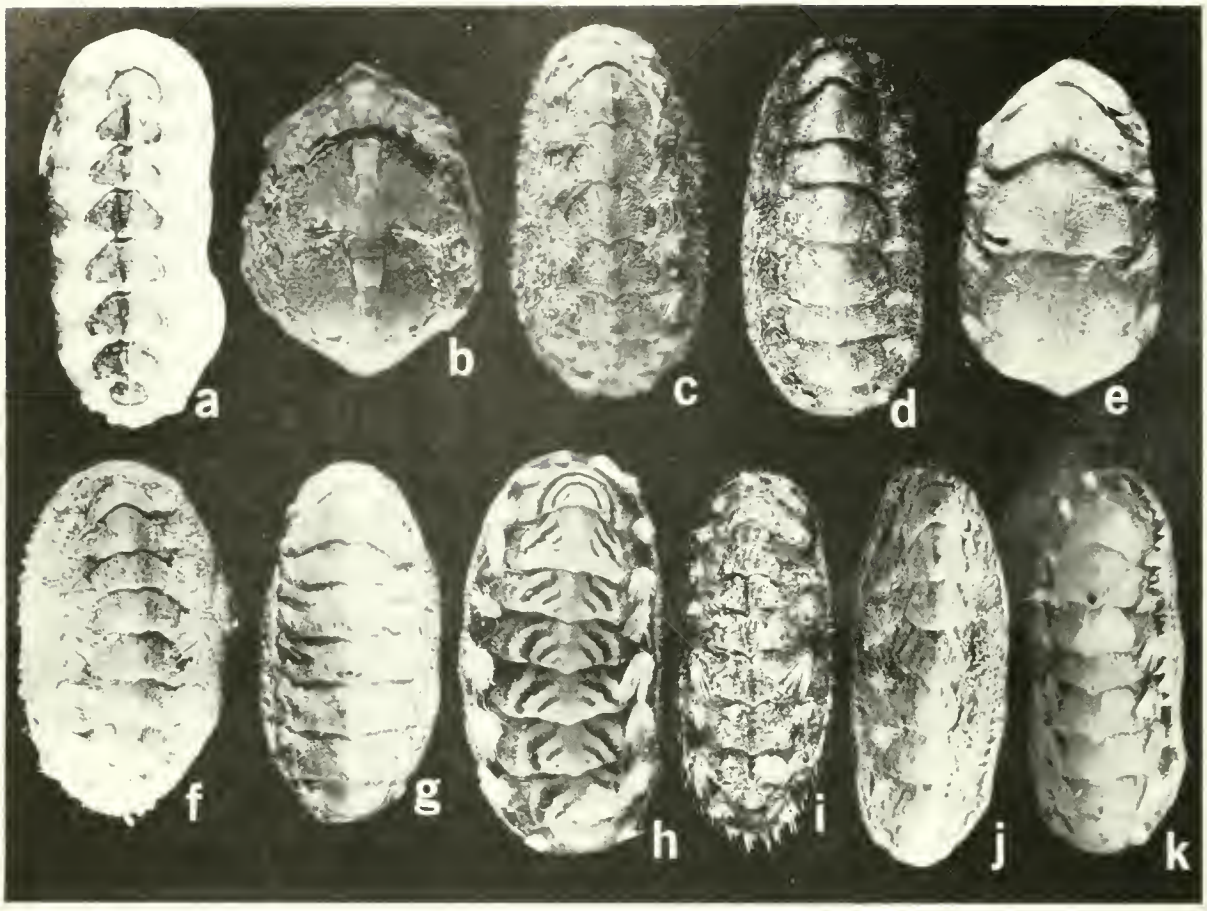

PLATE 4. **(a):** Acanthochitona communis *(Risso, 1826), Bullock collection, Azores Islands, 12 mm in length.* **(b):** Acanthochitona imperatrix *new species, Holotype USNM 218762, off San Diego, California, 8.9 mm in length, curled.* **(c):** Acanthochitona avicula *(Carpenter, 1864), Watters collection, Ensenada, Mexico, 15 mm in length.* **(d):** Acanthochitona avicula *(Carpenter, 1864), Lectotype of* A. avicula *variety* diegoensis *(Pilsbry, 1893), ANSP 349330, off San Diego, California, 19 mm in length.* **(e):** Acanthochitona angelica *Dall, 1919, Holotype USNM 110346, Bahía de Los Angeles, Baja California, Mexico, 11 mm in length, curled.* **(f):** Acanthochitona spiculosa *(Reeve, 1847), Watters collection, northwest West Summerland Key, Florida, 11 mm in length.* **(g):** Acanthochitona spiculosa *(Reeve, 1847), Lectotype of* A. pygmaea *(Pilsbry, 1893), ANSP 35783, Key West, Florida, 9 mm in length.* **(h):** Acanthochitona astriger *(Reeve, 1847), DMNH 45381, Water Island, Virgin Islands, 11 mm in length.* **(i):** Acanthochitona andersoni *new species, Holotype ANSP 332171, Calliaqua, St. Vincent, 11 mm in length.* **(j):** Acanthochitona balesae *Abbott, 1954, USNM 535950, Bonefish Key, Florida, 10 mm in length.* **(k):** Acanthochitona arragonites *(Carpenter, 1857), Watters collection, Salinas, Ecuador, 4 mm in length.*

of the intermediate valves of *A. arragonites* and *A. andersoni* tend to radiate from the beak; in *A. balesae* they are parallel to the jugum. Examination of museum collections has shown that *A. balesae* is widely distributed in the Caribbean and is more variable than was previously realized. Keys to *A. acerissa* and *A. elongata* (both 1972) are [illegible]. The lectotype of *A. balesae*, herein designated is ANSP 349331 from Bonefish Key, Florida.

ACKNOWLEDGMENTS

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the museums cited herein are to be thanked for their time and the loan of specimens. This research was made possible by a grant from Sigma Xi and a scholarship from the National Capital Shell Club.

The latter species is named in honor of Mr. Burton Anderson of Hollywood, Florida, who introduced me to malacology.

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WHAT IS *VENERICARDIA MORSEI* DALL?

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While I was preparing my review of the northwest American Carditidae, I examined the type material of *Venericardia (Cyclocardia) morsei* Dall, 1918: 234, described from "Sagami, Japan." The type material (USNM 274075), in contrast, is labeled as coming from another locality, "Kii, Japan." I concluded that, of eastern Pacific species, *V. (C.) morsei* was closest to but separable from *Cyclocardia crebricostata* (Krause, 1885) (Coan, 1977: 379).

Habe (1978: 99–100; figs. 5–8) has recently expressed the view that the type material of *Venericardia morsei*, which he illustrates for the first time, is conspecific with *Cyclocardia crassidens* (Broderip & Sowerby, 1829), a species characteristic of the eastern Pacific, par-

ticularly the Arctic and Bering seas. He also said that no additional specimens have come to light in recent years from either, well-studied Japanese locality.

I concur with Habe that the type material is probably not Japanese, but I cannot agree that it is conspecific with *Cyclocardia crassidens*. After examining carditids in the U.S. National Museum of Natural History, I am of the opinion that instead it is closer to *Cyclocardia borealis* (Conrad, 1832) of the western Atlantic, particularly to USNM 445701 from Mt. Desert, Maine.

The type lot of *Venericardia morsei* contained opposite valves of similar size from two individuals. The right valve is here designated the **lectotype** and measures 25.2 mm in length, 27.5 mm in height, and 7.9 mm in thickness. This specimen remains in USNM 274075. The left valve, which measures 24.5 mm in length, 27.9 mm in height, and 7.0 mm in thickness, is unusual in that it appears to be the product of hinge transposition. This **paralectotype** has been renumbered USNM 784633.

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A NEW BRASILIAN *PYRENE* (PROSOBRANCHIA: COLUMBELLIDAE)

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and

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In September 1978, the fisherman, Dorismundo Pinto, collected off Maricá, Rio de Janeiro State, 80 meters in depth, entangled in a lost net, 8 specimens of a Columbellidae which we believe is a species new to science.

For the time being, we have placed this species within the genus *Pyrene* and the subgenus *Conella* due to its characteristics and because it was not possible to save the radula.

Pyrene ledaluciae *new species*

Description: Shell fusiform, biconic, 24.4× 12.1 mm, [illegible] biconic, forming an apical angle of about 60°. Protoconch smooth, mammilliform, light-brown in color, with two whorls. Teleconch with six whorls, slightly convex. Suture well-impressed, but not channeled. Aperture ovate, long (3/5 of total shell length), violet internally. Operculum corneous, oval, yellow, with terminal nucleus. Outer lip not thickened, acute, with 12 denticles or lirae, the front 9 separated from the last 3. Outer surface bright, ornamented with microscopic spiral striae, more prominent on the spire and scarcely visible on the body whorl. Color brown with whitish yellow stains irregularly spotted.

FIG. 1. *Immature paratype and holotype (24.4 mm) of* Pyrene (Conella) ledaluciae *Rios and Tostes, new species, from off Marica, Rio de Janeiro State, Brazil.*

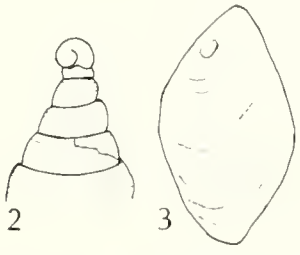

FIG. 2 *and* 3. *Protoconch and operculum of* Pyrene ledaluciae *Rios and Tostes, new species.*

Periostracum not apparent. Siphonal canal short, straight and open.

Only 2 species of the subgenus *Conella* – *ovulata* (Lamarck, 1822) and *C. ovuloides* (C. B. Adams, 1850) – are known in the Western Atlantic, both living in Florida and the Caribbean Sea. Our species is distinguished from the former by the protoconch, spire, aperture and form of denticles. It differs from the latter by the general shape, spire and aperture.

The holotype and a young specimen have been cataloged in the Malacological Laboratory of the Rio Grande Oceanographic Museum under no. 20.518. Paratype no. 1 is in the Malacological Collection of the junior author under no. 1781; paratype no. 2 is in the National Museum of Rio de Janeiro under no. 3.900; paratype no. 3 is in the American Museum of Natural History of New York under no. 183.263.

The authors wish to thank Dr. R. Tucker Abbott and Prof. Paulo Sá Cardoso (Maceió, Alagoas, Brasil) for their valuable suggestions, and thank Eng. Thierry J. Rios for the photos.

Measurements (mm):

	length	width	length of aperture	width of aperture
holotype	24.4	12.1	13.1	3.3
paratype 1	27.2	12.2	14.5	3.8
paratype 2	21.6	12.5	14.5	3.1
paratype 3	24.6	12.0	14.2	3.4

This species is named after the wives of the authors, Leda Rios and Luci Tostes.

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ANODONTA SPECIES OF LAKE McCONAUGHY, WESTERN NEBRASKA

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ABSTRACT

This is the first report of bivalves from Lake McConaughy, the largest reservoir in Nebraska. Two, or possibly three, species of the genus Anodonta *(Bivalvia, Unionidae) were found live from fourteen sites, over an area of 1,400 square meters, in depths ranging from three to five meters of water.*

Lake McConaughy is formed by Kingsley Dam, completed in 1941, across the North Platte River in southwestern Nebraska. The reservoir is located in Keith County, thirteen km north of Ogallala, Nebraska, and thirty-six km northwest of the Colorado-Nebraska state line, at approximately 101° north longitude, and 41.5° west latitude. The lake is thirty-five km long, six and a half km wide for some distance above the dam, and is forty-six m deep near the dam (Fig. 1). It has a shoreline of 170 km and a surface area, when full, of 14,165 ha. Since the dam was put into operation in 1941, Lake McConaughy's greatest storage was in July of 1951, at 23.6×10^8 m^3 and its lowest in October of 1956 at 4.72×10^8 m^3 (CNPPD, 1965b).

Lake McConaughy, Nebraska's largest reservoir, is the backbone of Central Nebraska Public Power and Irrigation District, the state's largest irrigation project. The primary purpose of this reservoir is to supplement the irrigation needs of the agricultural community below the dam; consequently water levels fluctuate dramatically throughout the year, with significant effects on the fauna of the lake.

Comparative ecological studies on temperature, oxygen concentration, water chemistry, and fluctuating water levels as factors influencing the fish population of Lake McConaughy have been the focus of continuing studies by the state's fishery department (Taylor, 1979). Little work, if any, has been conducted in identifica-

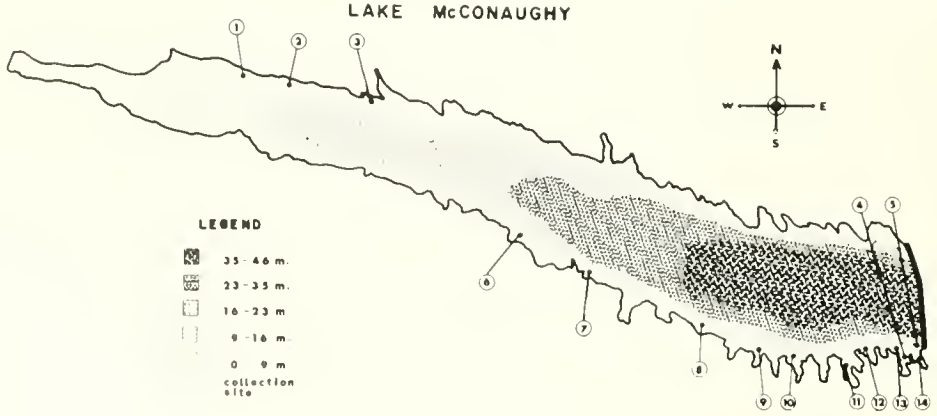

FIG. [illegible] McConaughy showing water depth and distribution of collection sites, each [illegible] square meter underwater quadrat.

tion or collection of the freshwater invertebrates which inhabit this reservoir. I have found no mention in the literature of any malacological studies conducted on the Lake McConaughy reservoir, and, according to experts in this field, little research has been carried out on this subject in the area of western Nebraska. This paper is the first report on the collection and identification of two species of unionacean clams conducted in the McConaughy reservoir during August of 1980.

MATERIALS AND METHODS

Fourteen collection sites were selected at random within the reservoir (Fig. 1). Because of the vast surface area of the lake, and depth of the water, a small boat and scuba equipment were utilized in collecting the specimens from the lake substrate. Survey materials included red survey flags, tape measures, compasses, and depth gauges of U.S. Diver 100 meter accuracy. At each site, one 10×10-meter quadrat was established, with the survey flags placed at one meter intervals to outline the 100 square meter quadrat. The specimens were removed and placed live in a tank aboard the boat, and marked by collection site number. In excess of thirty-five man-hours were spent searching the lake bottom.

The specimens were taken to the Cedar Point Biological Station, operated by the University of Nebraska, located at Lake Keystone, Keith County, to be identified and preserved for further reference. The shells are now in the collection of Dr. D. H. Stansbery, Director of the Museum of Zoology, Ohio State University, Columbus.

For each specimen, a complete description of the physical environment (i.e., relative turbidity, depth, and composition of the substrate) from which it was collected was recorded, as well as the length and weight of each specimen. From these records, the data was compiled by collection site and species collected (Table 1). To obtain further data on the numbers and habitats of the unionacean clams, area divers were enlisted to complete a modified data log of the number of bivalves observed, location of the observation, and composition of the substrate where the bivalve was observed during routine dives.

DISCUSSION AND RESULTS

Sixteen specimens were collected during this study, all belonging to the genus *Anodonta*, a unionacean clam common to North America. The majority of the specimens were collected in 3 to 5 m of water, and none under 2 m. Most were on a sand-silt substrate.

Specimens were identified by Dr. D. H. Stansbery, Ohio State University as *A. imbecillis*, *A. grandis*, and *A. grandis dakota*. They are described below.

One specimen (MDB14) was found to be *A. imbecillis* Say, 1829. It was 9.1 cm long, and was collected in five meters of water (Figure 1). This species is widespread from Mexico in the southwest, throughout the central and lower Mississippi River system, in Lake Erie, and tributaries and in rivers (including impoundments) to the Atlantic coast from Florida north to at least Maryland. It is a member of the subgenus *Anodonta*, the old world *Anodonta* species, as are several other North American species (Burch, 1973).

The remaining 15 specimens belong to the *A. grandis* Say, 1829, complex of the subgenus *Pyganodon*. These are the new world *Anodonta*, and a few species of this subgenus are found in Asia. This species is common throughout the Mississippi River basin, and most of the eastern United States (Burch, 1973). Twelve of them are *A. grandis grandis* Say, 1829.

Three of the larger bivalves taken from the base of the dam (MDB8, MDB4, JEF15), were identified as *A. grandis dakota* Frierson, 1910. This clam is distinguished from *A. grandis grandis* by a straw-colored periostracum, beaks (or umbo) low, double-loop umbonal sculpture, rayless, no central swelling of the disc, and the posterior extreme frequently being near the base line (Frierson, 1910). It was described as a new species from specimens found in Clear Lake, Deuel County, South Dakota, 1909; Frierson reported *A. grandis grandis* from the same lake. It is not known at this time whether *A.*

TABLE 1. *Distribution and statistics of species collected at Lake McConaughy, Keith County, Nebraska*

Collection site number	Specimen identification number	Species	Length (m.)	Length (g.)	Composition of substrate	Depth of collection (m.)	Relative Turbidity (i.e. visibility) (m.)
1	--	--	--	--	Mud Bottom	4	≤ 1
2	--	--	--	--	Mud Bottom	3	≤ 1
3	--	--	--	--	Mud Bottom	3 - 4	≤ 1
4	MDB1	A. grandis grandis	0.150	278.5	Fine Sand/	3 - 5	5 - 7
	MDB2	A. grandis grandis	0.144	270.5	Silt with		
	MDB3	A. grandis grandis	0.155	370.0	large rocks		
	MDB4	A. grandis dakota	0.160	386.0			
5	JEF15	A. grandis dakota	0.132	209.0	Fine Sand/	5 - 7	5 - 7
	MDB16	A. grandis grandis	0.086	54.3	Silt with large rocks		
6	--	--	--	--	Sand/Silt	4 - 7	≤ 2
7	--	--	--	--	Sand/Silt	4 - 7	≤ 1
8	--	--	--	--	Sand/Rock	4 - 7	≤ 1
9	--	--	--	--	Sand/Rock	4 - 7	≤ 2
10	--	--	--	--	Large rocks	4 - 9	5 - 7
11	MDB11	A. grandis grandis	0.200	880.0	Fine Sand/	4 - 9	≥ 5
	JEF12	A. grandis grandis	0.179	516.0	Rocks		
	JEF13	A. grandis grandis	0.148	294.8			
12	--	--	--	--	Sand/Gravel	4 - 8	5
13	MDB14	A. imbecillis	0.091	42.3	Sand/Rock	4 - 9	5
14	MDB5	A. grandis grandis	0.137	232.2	Fine Sand/	4 - 7	5
	JEF6	A. grandis grandis	0.201	820.0	Silt		
	JEF7	A. grandis grandis	0.130	235.0			
	MDB8	A. grandis dakota	0.157	355.8			
	JEF9	A. grandis grandis	0.188	790.0			
	MDB10	A. grandis grandis	0.144	312.0			

grandis dakota is 1) a distinct species, or 2) a subspecies of *A. grandis*, or 3) an environmental form of *A. grandis grandis* (Stansbery, pers. comm.). However, consistently finding both *A. g. grandis* and *A. g. dakota* in the same lake argues against environmental forms, if one assumes that environments are uniform throughout the reservoir. Note that although I found *A. g. grandis* in some relatively shallow, fluctuating environments, some were found in sites with *A. g. dakota;* it is not likely that the environmental conditions of MDB8 and MDB5 (Table 1, Fig. 1) are appreciably different.

Lake McConaughy was formed in 1941 from

the North Platte River (part of the Missouri River drainage) and has been repeatedly stocked with game fish from sources both in the United States and Canada by the Nebraska Game and Parks commission (Nebraska Game, Forestation, and Parks Commission, 1958–79). Since *Anodonta* spp. are known from the eastern part of the Missouri drainage and Wyoming, but may also be carried as parasitic larvae by stocked fish (Pennak, 1958), it is impossible to determine the source of the clams. Other lakes do not occur naturally along the Platte, and the North Platte River formerly went dry in late summer. Therefore, it seems likely that *Anodonta* abundance has greatly increased since the completion of Lake McConaughy. The presence of *Anodonta* in the Sandhills Lakes northwest of Lake McConaughy seems unlikely because of their unusual chemistry (McCarraher, 1977), and lack of outlets. I do predict their presence in comparable reservoirs in the region (e.g. in Kansas and Colorado).

The specimens ranged in length from 8 to 21 cm, with a live weight averaging 450 g. The distribution was skewed to large clams; none under 8 cm were found. While this could indicate the absence of small individuals from Lake McConaughy, I believe it is due to the difficulty of locating small clams in the poor visibility of the bottom (usually under 3 m). The substrate of Lake McConaughy is sand, but a thin layer of silt is found in the deeper waters toward the dam. 12 of the clams were found on the sand-silt; only 4 clams (*A. g. grandis* and *A. implicatus*) were collected on sand-rock substrates (Table 1).

Of the larger clams collected (MDB4, JEF6, MDB8, JEF9) the majority were found in deeper waters located in the coves at the base of the dam (Fig. 1). This area should be the most stable in terms of water level fluctuations due to the fact that it is closer to the dam and should therefore maintain a higher, more constant level of water.

No *Anodonta* individuals were found in depths less than 2 m, despite searching at least 400 m². This result is confirmed by area divers, who reported seeing 70 additional clams, all in depths of 3 to 5 m. Therefore, *Anodonta* appears to be confined to the perimeter waters (3–5 m deep) of this reservoir. Since the study was conducted in August of the year in which the lake was high until quite late in the season, it is likely that these depths represent early summer levels, and that minimum depths of perhaps slightly under 2 m are experienced at those sites only at lowest storage. This suggests that *Anodonta* is uncommon in the shallow (rarely 2 m deep for any extended period of time) North Platte River.

No other mollusks were observed; presumably they are rare or absent.

ACKNOWLEDGMENTS

I wish to thank Dr. K. Keeler for her support and direction in this project; J. Ferguson, my diving partner; Dr. D. H. Stansbery for identifying specimens; and J. Palmer for editing and typing this manuscript. A special thanks to the Cedar Point Biological Station operated by the University of Nebraska for the use of its facilities and equipment during this project, and especially to its Director, Dr. J. Janovy, Jr., and his wife, Karen, for the most memorable summer of my life.

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PROTANDRY WITH ONLY ONE SEX CHANGE IN AN *EPITONIUM* (PTENOGLOSSA)

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ABSTRACT

Reports conflict on whether ptenoglossans undergo more than one sex change, although since 1926 they were always reported (with few supporting data) to be protandric. Small individuals of the West Indian wentletrap Epitonium albidum *(Orbigny, 1842) (shell length <8 mm) were found to be males (with spermatozeugmata in their gonads), and large individuals (shell length >? mm) were females (with oocytes and ova). Hermaphroditic individuals ranged in shell length from 5 to 8 mm. The data support the idea of protandry with only one sex change in* E. albidum. *Males and females attain larger sizes in the British Virgin Islands than at Barbados.*

The Epitoniidae (= "Scalariidae" or "Scalidae") and Janthinidae, two ptenoglossan families, have at various times been considered to have separate sexes, or to be simultaneous hermaphrodites or to be protandric hermaphrodites. Cuvier (1808:129) believed that the sexes are separate in *Janthina*, but Quoy and Gaimard (1832:247) believed *Janthina* to be hermaphroditic. Pruvot-Fol (1925), who studied histologic sections of two *Janthina* animals, thought that they are simultaneous hermaphrodites and that they possibly self-fertilize.

Ankel (1926:196) stated that *"Scala"* [= *Epitonium*] and *Janthina* are protandric. The meager data published subsequently (Table 1) support this conclusion, but there is disagreement on whether there is more than one sex change. Fretter and Graham (1962:377–378) summarized the situation well.

Ankel (1936:149) stated that in *"Scala"* [= *Epi-*

TABLE 1. *Authors since Ankel (1926) who have concluded that ptenoglossans are protandric.*

Author	*Species studied*[1]	*Only one sex change*	*More than one sex change*
Ankel, 1930: 496–502, fig. 3	*Janthina pallida*	+	
Ankel, 1936: 149–150, fig. 128	*Epitonium clathrus*		+
Lützen, 1953: 8–14	*Janthina* spp.		+
Graham, 1954	*Janthina janthina*	+	
Bulnheim, 1962: 302–304	*Opalia funiculata*		+
Bulnheim, 1968: 234	*Epitonium tinctum*		+
Breyer, 1980	*Epitonium tinctum*	+	
Robertson, [illegible]	*Epitonium millecostatum*	+	
Robertson, [illegible]	*Epitonium albidum*	+	

[1]Nomenclature brought up-to-date.

tonium] clathrus (Linn., 1758) there is sex reversal accompanying each breeding season (it is not stated when the breeding season occurs, or how long the *Epitonium* lives).

The purpose of this paper is to determine from a large series of specimens whether the West Indian wentletrap *Epitonium albidum* (Orbigny, 1842) is protandric and whether it undergoes more than one sex change.

MATERIALS AND METHODS

Epitonium albidum, a symbiont with the actiniarian *Stoichactis helianthus* (Ellis and Solander, 1786) (Robertson, 1963:52–53), was studied at Virgin Gorda Feb.-Mar. 1972 and Barbados Mar.-April 1980. The shell length of each specimen was recorded, and the shell was cracked or dissolved (in weak hydrochloric acid or in Bouin's solution). Gonads were examined with a Wild dissecting microscope at 50×. Spermatozeugmata (densely packed in the gonad, especially to the right of the stomach) and oocytes and ova could readily be distinguished. Individuals termed hermaphroditic had spermatozeugmata proximally in the gonads and oocytes and ova distally.

RESULTS

The data are given in Fig. 1. Ninety-three individuals were sexed—39 from the British Virgin Islands and 54 from Barbados. Fifty-three animals, ranging in shell length from 1 to 8 mm, were males, and twenty-nine animals, ranging in length from 7 to 16 mm, were females. Eight animals, ranging in length from 5 to 8 mm, were hermaphrodites, and three additional animals, ranging in length from 2 to 4 mm, were immature. An animal 8 mm long was seen to shed spermatozeugmata and was later sexed as a female (it was categorized as a hermaphrodite). The sex ratio was 59% male, 9% hermaphrodite and 32% female.

The largest Barbados males were 6 mm long, while the largest British Virgin Island males were 8 mm long. British Virgin Island females ranged up to 16 mm; one Barbados female was 14 mm, and the others were 11 mm or less in length. (According to Clench and Turner (1951: 260–261), *E. albidum* attains a length of about 21.5 mm.)

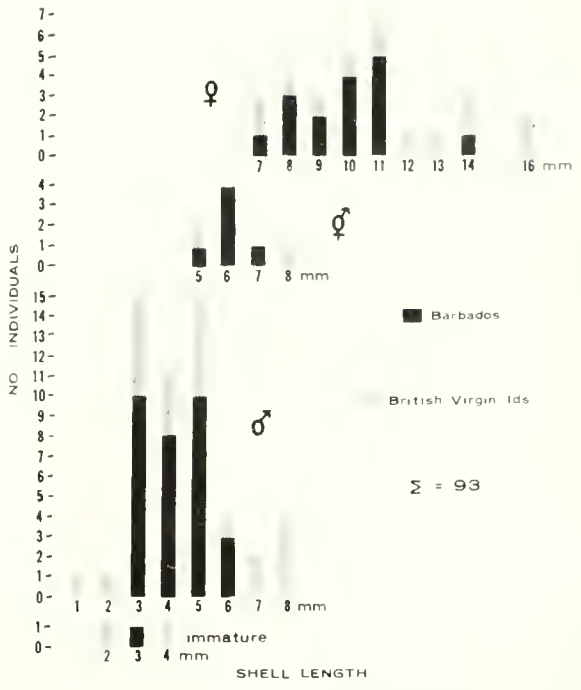

FIG. 1. *Shell lengths of immature, male, hermaphrodite and female individuals of* Epitonium albidum *from Barbados and the British Virgin Islands.*

CONCLUSIONS

The data given here on *Epitonium albidum* support the concept that at least this species is strictly protandric, that is, it first becomes male and later becomes a female between shell lengths of 5 and 8 mm. All the individuals longer than 8 mm were females. There is no evidence that these females ever change back into males. The proximally (anteriorly) located spermatozeugmata of the hermaphroditic individuals indicate that these were changing from the male to the female phase and not vice versa.

The above conclusions are consonant with those on *Janthina* by Ankel (1926, 1930) and Graham (1954), and other species of *Epitonium* by Breyer (1980) and Robertson (1981). The statements by Ankel (1936) and Bulnheim (1962, 1968) about epitoniids alternating their sex more than once require substantiation.

Male and female *Epitonium albidum* attain larger sizes in the British Virgin Islands than at Barbados.

ACKNOWLEDGMENTS

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CHICOREUS (CHICOMUREX) TURSCHI, A NEW MURICIDAE FROM NEW GUINEA

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Chicoreus (Chicomurex) turschi n. sp.
(Figs. 1–6)

Description: Shell small for the subgenus, solid, size variable, from 28 to 40 mm in adult specimens. Spire moderately high. Color generally cream with 3 brown bands on varices of the last whorl; the first one immediately under the shoulder of the body whorl, the third one on the lower part of the varices, the second one situated between these two, generally closer to the

(see opposite page)

FIGS. 1–9. [illegible] (Chicomurex) turschi *R. Houart sp. nov. Holotype I.R.S.N.B. no. 374, 30 mm.* **3**, *Paratype, R. Houart collection.* **4**, *Paratype I.R.S.N.B. no. 375, 24.2 mm.* **5**, *Protoconch and first whorls (same specimen as fig. 4).* **6**, *Protoconch and [illegible].* **7**, *Chicoreus* (Chicomurex) venustulus *Rehder & Wilson, 1975. Holotype USNM 707241, ×2.* **8**, *Protoconch and [illegible] USNM 707245, ×10.* **9**, *Reproduction of protoconch after figure 8.*

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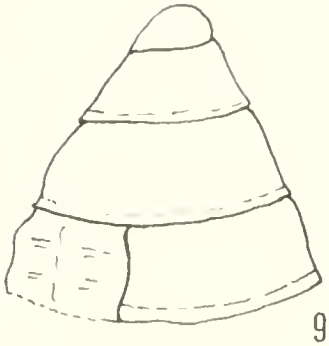
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third one. These brown bands sometimes extended on to the body whorl; coloration sometimes present on the first whorls but almost invisible. Brown spots most apparent on the suture of the whorls. Completely orange or albino examples known.

Aperture bluish white and oval, slightly angular; anal notch well-delimited; columellar lip adherent to the shell posteriorly and detached below; 3 or 4 little denticles on the anterior end and many fine folds on the posterior end with a more apparent denticle, delimiting the anal notch; color white. Outer apertural lip finely crenulated; interior of the outer lip entirely spirally ridged. Operculum muricine with an apical nucleus.

Spire consisting of one and one-half nuclear whorl, glossy and smooth and 6 or 7 postnuclear whorls. From the first whorl 3 varices and 3 or 4 axial costae, changing on the last whorl to one very prominent axial node and a smaller secondary one.

Spiral sculpture of body whorl consisting of 7 or 8 principal ridges; generally not too scabrous and flanked on each side by 1 or 2 finer and scabrous cords. A fine spiral cord also situated between these ridges. These ridges extended on to the varices, very scabrous especially on the adapertural side where there are crowded lamellae. On the varices, spiral ridges producing short open spines, slightly recurved and most visible on the body whorl. These spines are longest on the shoulder and on anterior part of the last whorl where they are flanged. Siphonal canal open, moderately long for the subgenus and slightly recurved on the end; ornamented with 3 or 4 ridges, producing short open spines, slightly posteriorly recurved. Holotype 30 mm in length; 16 mm in width.

Type material: Holotype (in the Institut Royal des Sciences Naturelles de Belgique in Brussels) I.R.S.N.B. no. 374; 3 paratypes I.R.S.N.B. no. 375; 2 paratypes Brit. Mus. (N.H.) 198089; 2 paratypes Amer. Mus. Nat. Hist. 196023 & 196024; 2 paratypes United States Nat. Mus. 784589; 2 paratypes Houart collection. All from the type locality.

Type locality: Hansa bay, Papua New Guinea, off Durangit, 45-60 m, with sponges. Paratypes also from Rabaul, Papua New Guinea.

This shell may be compared with *Chicomurex venustulus* Rehder & Wilson. Three important differences separate them:

1) *Ch. turschi* has a much more fusiform shell, much more slender, and, in most cases, smaller.

2) *Ch. venustulus* has a conical carinate protoconch consisting of three and one-half whorls. *Ch. turschi* has a convex protoconch, glossy and smooth, consisting of one and one-half whorl and never carinate.

3) *Ch. venustulus* has stronger lirations on the columellar lip. *Ch. turschi* always has a smooth columellar lip, except for the fine posterior folds and 2 or 3 anteriorly denticles.

The color, if not important, also separates the two species: rose or orange in *Ch. venustulus;* brown and white in *Ch. turschi* (somewhat as in *Naquetia)* although the latter may be rarely solid orange or albino.

It is a great pleasure to name this shell in honor of Professor Ben Tursch who so kindly let me examine all the specimens of this new species and other members of the family Muricidae.

ACKNOWLEDGMENTS

I wish to thank, of course, Prof. B. Tursch but also Dr. Harald A. Rehder of the National Museum of Natural History, Washington, who sent me a reprint of his paper concerning *Ch. venustulus* and some photographs which are here illustrated. I am also grateful to Mr. G. Poppe of Mortsel, Belgium, for some photographs, and to Dr. Emily Vokes, Tulane University, who revised and commented upon the manuscript.

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LAMINOPLAX, A NEW GENUS OF CHITONS AND THE TAXONOMIC POSITION OF *HANLEYA DALLI* KAAS, 1957 (POLYPLACOPHORA: AFOSSOCHITONIDAE).

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ABSTRACT

The examination of the holotype of Hanleya dalli *Kaas, 1957 [new name for* Lepidopleurus carinatus *Dall, 1927 (not Leach, 1852)] revealed that this species, with its elongated body, thick valves, granulo-vermicular tegmentum, spiculoid girdle, posterior gills, and well-developed, unslit insertion plates in all valves belongs in the family Afossochitonidae. A new genus,* Laminoplax, *is proposed to accommodate the species.* Laminoplax dalli *is known only from the type material, off Eastport, Maine.*

In 1927 Dall described, but did not illustrate, a new species of chiton, *Lepidopleurus carinatus*, based on material from Eastport, Maine. In 1957 Kaas pointed out that Dall's name had been preoccupied by Leach (1852), and proposed the name *Hanleya dalli* for the taxon. In the course of a review of the family Lepidopleuridae (Ferreira, 1979), I have had the opportunity to examine the holotype, and only known specimen, of this taxon. The purpose of this paper is to redescribe and illustrate this species, reassign it to a different family and a new genus, and to discuss the classification of the Lepidopleurina. The holotype and other comparative material were made available through the courtesy of Dr. Joseph Rosewater, National Museum of Natural History, Washington, D.C. [USNM].

Systematic Treatment

POLYPLACOPHORA Blainville, 1816

Order **Neoloricata** Bergenhayn, 1955

Suborder **Lepidopleurina** Thiele, 1910

Definition: Valves without insertion plates, or with insertion plates without slits (Van Belle, 1975:135).

Remarks: In the classification of chitons, articulamental features, and, in particular, the presence or absence of insertion plates and slits have been considered characters of fundamental importance (Pilsbry, 1892–1894; Knorre, 1925; Ashby, 1929; Thiele, 1929; Bergenhayn, 1955; Smith, 1960; Van Belle, 1975–1978). Thus, the orders Paleoloricata Bergenhayn, 1955, and Neoloricata Bergenhayn, 1955, were defined, respectively, by the absence or presence of sutural laminae in the articulamentum. The Lepidopleurina, generally recognized as the most primitive of Recent chitons [present since the Ordovician], has been divided, on the basis of the insertion plates, into four families (Van Belle, 1975): Lepidopleuridae Pilsbry, 1892 (all valves devoid of insertion plates), Protochitonidae Ashby, 1925 (insertion plates absent in the end valves but present, although unslit, in the intermediate valves), Hanleyidae Bergenhayn, 1955 (unslit insertion plate present in front valve, but absent, or only vestigial, in posterior valve; intermediate valves without insertion plates), and Afossochitonidae Ashby, 1925 (unslit insertion plates present in all valves).

Afossochitonidae Ashby, 1925

Definition: Unslit insertion plates present in all valves (Van Belle, 1975:147).

Type genus: Afossochiton Ashby, 1925 (Type species: *Afossochiton cudmorei* Ashby, 1925 [fossil, Oligocene], by original designation).

Remarks: Ashby (1925) established the taxon Afossochitoninae as a subfamily of Acanthochitonidae Pilsbry, 1893 [erroneously attributed to

Hedley, 1916], with a single genus, *Afossochiton* Ashby, 1925, and two fossil species, *A. cudmorei* Ashby, 1925, and *A. rostratus* (Ashby & Torr, 1901), of the Oligocene of Victoria, Australia. Bergenhayn (1955) considered the taxon Afossochitonina as one of the four suborders in his Neoloricata, in view of its lepidopleurid configuration, achantochitonid sculpture, and an articulamentum represented only by sutural plates (Bergenhayn, op. cit., pp. 38–40). Smith (1960) adopted the same interpretation. However, Bergenhayn's view was incorrect. As Van Belle (1975) pointed out, Ashby (1925) did describe insertion plates in the intermediate valves of the type species, *Afossochiton cudmorei*, in addition to the fact that, later, the description of several other species of *Afossochiton* by Ashby & Cotton (1939) [*A. sulci*, *A. dendus*, *A. iscus*, and *A. magnicostatus*] left no doubt about the presence of insertion plates in all valves of the specimens under consideration. Thus, Van Belle (1975:143) concluded that "Bergenhayn's [and Smith's] position is untenable", and that Afossochitonidae should be classified in the Lepidopleurina.

The definition of Afossochitonidae contains no statement concerning the gills, three of the genera being known only as fossils, and the only member of *Choriplax*, *C. grayi* (Adams & Angas, 1864), known only from the type specimen [and another questionable one reported by Ashby (1921)], has been cited only a few times in the literature (Adams & Angas, 1864:194; 1865: plt. 11, figs. 16, 17; Angas, 1867:222; Pilsbry, 1893:21–22, plt. 6, figs. 9–11, with notes from Carpenter's unpublished manuscript; Ashby, 1921:136–142, plt. 9; Iredale & Hull, 1925:99–100, plt. 11, figs. 24–28) with no mention of the gills. It is worth noting that although Ashby (1921) placed Choriplax in the Acanthochitonidae, Pilsbry (1893), Thiele (1910), Smith (1960), and Van Belle (1975) allocated it to the Lepidopleurina.

In the Afossochitonidae, Van Belle (op. cit.) recognized four genera: *Glyptochiton* Koninck, 1883 [Carboniferous], *Afossochiton* Ashby, 1925 [Oligocene–Miocene], *Lirachiton* Ashby & Cotton, 1939 [Oligocene], and *Choriplax* Pilsbry, 1894 [Recent].

Laminoplax Ferreira *gen. nov.*

Definition: Elongated, carinated chitons, with thick valves. Obsolete lateral areas. Tegmentum with granulo-vermicular sculpture. Girdle covered with spiculoid processes. Gills posterior. Articulamentum with slitless insertion plates in all valves.

Type species: Hanleya dalli Kaas, 1957 [new name for *Lepidopleurus carinatus* Dall, 1927 (not Leach, 1852)] by original designation, herein.

Laminoplax dalli (Kaas, 1957)
(Figs. 1–6)

Synonymy:
Hanleya dalli Kaas, 1957:83
Lepidopleurus carinatus Dall, 1927:11 (non Leach, 1847, *nude name*; non Leach, 1852).

Type locality: Eastport, Maine [44°54′ N, 67°00′ W]. *Holotype:* (USNM 225149).

Original description: "Shell rather large . . . yellowish white, densely covered with minute pustules which are obscurely arranged concentrically to the mucro of the posterior valve, radially on the anterior valve and longitudinally on the intermediate valves; back subcarinate, the angle about 70°; eaves projecting, the insertion plates of the terminal valves not split but radially rugose, of the intermediate valves entire; girdle narrow, densely pilose, with extremely fine close minute spinules, with alternating darker and lighter patches; central, jugal and lateral areas not defined; length in dry, curved condition about 35, diameter 9; height, 12 mm." (Dall, 1927:11).

Expanded Description: The holotype of *Lepidopleurus carinatus* Dall, 1927 (USNM 225149) is accompanied by a museum label which reads "Eastport / type / 1870 / Maine / Verrill," with question marks pencilled in by unknown hand after the words "Eastport" and "Maine." Specimen preserved dry, tightly curled; all valves broken, mostly longitudinally, with loose fragments of valves i, ii, iv, and v. Uniform cream color. Strongly carinate. Lateral areas obsoletely defined; tegmentum sculptured with vermicular, low profile rugosities disposed longitudinally in central areas, concentrically in valve i, postmucro area of valve viii, and lateral areas of intermediate valves (Figure 1). Valves

FIG. 1. *Holotype of* Laminoplax dalli *(Kaas, 1957). Close-up of valves vi and vii to show tegmental sculpture.*

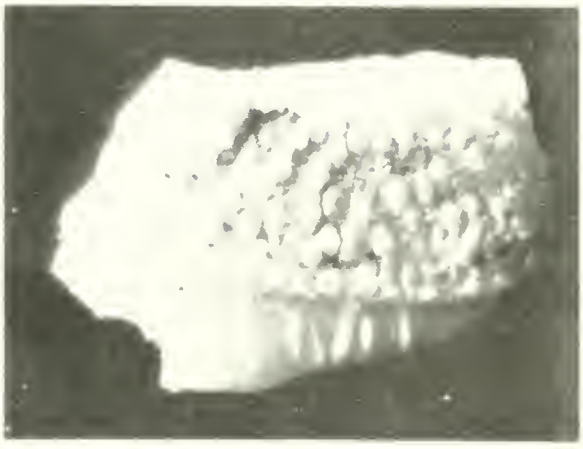

FIG. 3. *Holotype of* Laminoplax dalli *(Kaas, 1957). Close-up of fragment of anterior valve to show tegmental sculpture, and insertion plate with its fluted rugosities.*

remarkably heavy, up to 800 μm in thickness on valve iii. Insertion plates well developed in the anterior and intermediate valves, but limited to a ridge in the posterior valve (Figure 2), without slits or teeth, but with fluted rugosities on the outer surface (Figure 3). Sutural laminae relatively large, separated by a well defined sinus. Girdle pilose in appearance, covered uniformly with juxtaposed spicules (Figure 4), mostly straight, many broken (Figure 5) measuring up to 400 μm in length, 30 μm in thickness; undersurface covered with imbricated, flat, transparent, lanceolate scales, about 120×15 μm in dimentions (Figure 6). Gills short, posterior. Radula, still in place, not examined.

Remarks: Laminoplax dalli is known only from the type specimen. Although Dall (1927) in-

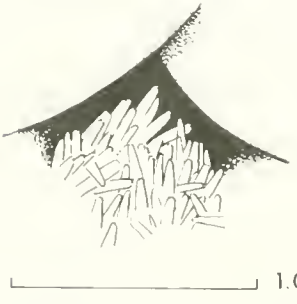

FIG. 4. *Holotype of* Laminoplax dalli *(Kaas, 1957). Girdle spicules at junction of plates.*

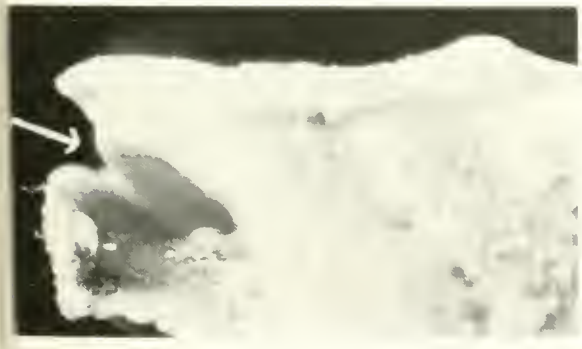

FIG. 2. *Holotype of* Laminoplax dalli *(Kaas, 1957). Close-up of posterior valve to show (arrow) side view of insertion plate, here limited to a ridge.*

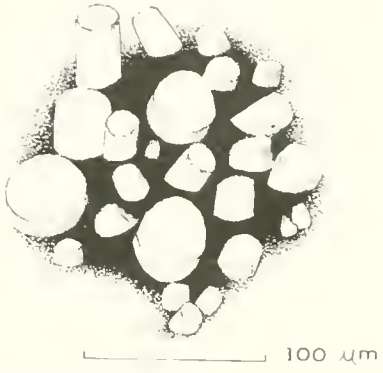

FIG. 5. *Holotype of* Laminoplax dalli *(Kaas, 1957). Girdle fragment to show spicules, mostly broken, reduced to stumps only.*

FIG. 6. *Holotype of* Laminoplax dalli *(Kaas, 1957). Scales on the undersurface of the girdle.*

dicated that more specimens of the species were available to him from Maine and Georges Banks, none were found. Three lots labelled "*Lepidopleurus carinatus* Dall" in the collections of the National Museum of Natural History, Washington, D.C. (USNM 10757; USNM 103477; USNM 34448), examined on a loan arranged through the kindness of Dr. Joseph Rosewater, proved to be misidentifications; no specimens so labelled were found in the Museum of Comparative Zoology, Harvard University, Cambridge, Massachussetts (Dr. Kenneth J. Boss, *in litt.*, 22 October 1979). There remains, also, some question about the depth at which the single specimen of *Laminoplax dalli* was collected. Dall (1927) did not include it in the original description of the species except for the ambiguous statement that "others" were found in 12 fathoms [22 m]; the accompanying museum label gives no indication of depth, either [the figure "1870" on the original label likely refers to the date of the collection, not to the depth].

In general shape, tegmental sculpture, girdle elements, and posterior gills, *Laminoplax dalli* is undoubtedly in the suborder Lepidopleurina. Despite assigning it to *Lepidopleurus*, Dall (1927:11) regarded the species as "intermediate between *Lepidopleurus* and *Hanleya*." Apparently based on this statement and Dall's description, and without examining the type material, Kaas (1957) assigned *dalli* to the genus *Hanleya*, instead. However, neither Dall's (1927) nor Kaas' (1957) generic assignment is correct. Present understanding of these two genera [*Lepidopleurus* having no insertion plates; *Hanleya* having insertion plates in the terminal valves but not in the intermediate valves] indicates that *dalli*, for the presence of slitless insertion plates in all valves, belongs in the Afossochitonidae, in a new genus, *Laminoplax*, here proposed.

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FRESHWATER SNAILS OF THE SENEGAL RIVER BASIN, WEST AFRICA[1]

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The Senegal River is the second largest river in West Africa. Its river system is about 1,800 kilometers long and drains an area of about 290,000 square kilometers. The Senegal River is formed by the union of the Bafing and Bakoye rivers at the town of Bafoulabe, about 1,060 kilometers upstream from the Atlantic Ocean. These two rivers, along with the Faleme River, supply almost all the flow entering the Senegal River.

This study on the freshwater snails of the Senegal River basin was carried out to assess the situation before two dams are built. One dam, an antisalt dam about 30 km upstream of Saint-Louis at the village of Diama, and a high flow regulatory dam at Manantali in Mali. The

[1]This study was carried out for the United States Agency for International Development, the State Department, and O. M. V. S., Dakar, through a contract with Gannett Fleming Corddry and Carpenter, Harrisburg, Pennsylvania. It is a part of a study on Assessment of Environmental Effects of Proposed Developments in the Senegal River Basin. Our thanks are due to Dr. Max Miller for encouragement.

Diama dam will create an impoundment of 235 square km and the Manantali dam an impoundment with a surface area of 477 square km.

Rainfall within the Senegal River basin is highly seasonal. In the southern part of the basin, there is a short dry period and the heaviest rains occuring between May and October. In the central and northern parts of the basin the rainfall is generally of the short duration, high intensity type. Rainfall in this area normally falls between July and September.

Reports on the snail fauna of the Senegal River have been few and have mainly included the bulinid and biomphalarid hosts of schistosomiasis. A brief reference was made to some of these hosts by Leger (1923) and by Lefron (1933). More information was given by Lariviere et al. (1963). Deschiens (1951) and Gaud (1955) lumped the bulinid hosts and referred to them as groups. Marill (1961), in his snail surveys in Mauritania, considered the Senegal River as the main source of spread of the snail hosts into various types of waterbodies supplied by the river water. Wright (1956, 1957) included Gambia in his reports, discussed the morphology of various bulinid snails in Senegambia and gave a key for their differentiation.

Mandahl-Barth (1958) treated the African snail hosts of schistosomiasis and included some West African species. Sellin et al. (1980) in their studies on the distribution of the snail intermediate hosts of schistosomiasis in West Africa, included Mali only in the Senegal River basin. They stated that they collected *Bulinus globosus*, *B. jousseaumei* and *B. senegalensis* in the Yanfolila region. The freshwater snails of Africa were treated comprehensively by Brown (1980). However, it is obvious that only a few species from the Senegal River basin were dealt with by Brown, on account of the scarcity of material from that part of Africa.

Field studies in the Senegal River basin were conducted by us during three, 1-month visits in 1977-1978 and a 2-week period in January 1979. Moreover, the junior author carried out an 18-month longitudinal study, the quantitative results of which will be published elsewhere.

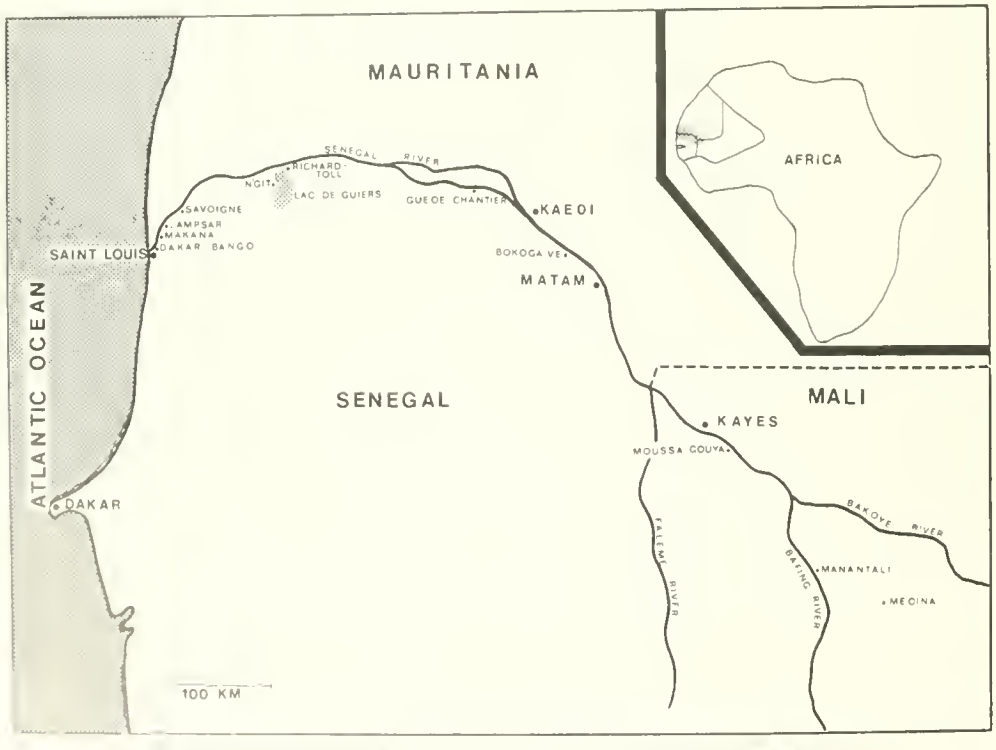

FIG. 1. *Senegal River basin encompassing parts of Senegal, Mali and Mauritania.*

RESULTS

The following snails were collected during the surveys. They are arranged by families and the localities where they were collected are indicated (also see Figure 1).

Family Planorbidae

***Bulinus (Bulinus) guernei* (Dautzenberg, 1890)**

Senegal: Lac de Guiers northern west tip at Pach; Lac de Guiers at N'Gnit village; temporary pond near Bokogawe, 48 km west of Matam; Irrigation canal, Guede Chantier rice plantation; Irrigation canals at Richard Toll, sugar-cane plantation; Dakar Bango, cement-lined canal for Saint Louis water supply; Irrigation canals leading to Kassak Sud; Large ponds on both sides of the road at Savoigne; Large pond, 6 km south of dam site at Diama; Lampsar Marigot at Lampsar and at Makhana; Large swamp under bridge near Matam.

Mali: Tributary of Bafing river about 63 km north of dam site at Manantali; Large pond at Medina, about 30 km southeast of dam site at Manantali; Senegal River at Moussa Gouya village, 25 km southeast of Kayes.

Mauritania: Reservoir at Dionaba dam site in the Brakna region.

***Bulinus (Bulinus) senegalensis* Müller, 1781**

Senegal: Pond near abattoir, Matam; pond at edge of Matam; laterite ponds at Ourossogui airfield.

***Bulinus (Bulinus) forskalii* (Ehrenberg, 1831)**

Senegal: Irrigation canals, Guede Chantier rice plantation; Irrigation canals, Richard Toll sugar-cane plantation; Lac de Guiers at several sites on east and west sides; Ponds at both sides of road at Savoigne; Pond about 6 km south of dam site at Diama; Lampsar Marigot at Lampsar and Makhana; Irrigation canals, Dagana rice plantation, about 20 km east of Richard Toll.

Mali: Pond at Medina about 30 km southeast of dam site at Manantali; Tributary of Bafing river about 63 km north of site at Manantali.

Mauritania: Rice plantation and pond near Rosso.

***Bulinus (Physopsis) jousseaumei* (Dautzenberg, 1890)**

Senegal: Lampsar Marigot at Lampsar and Makhana

***Bulinus (Physopsis) globosus* (Morelet, 1866)**

Mali: Pond at Medina, about 30 km southeast of dam site at Manantali.

Senegal: Small flood plain between Matam and Ourossoqui.

Mauritania: Reservoir at Choggar Sud-dam-site, Brakna region.

***Afrogyrus coretus* (Blainville, 1826)**

Senegal: Lac de Guiers at several sites on both sides; Swamp at Pahk village; Irrigation canals at Dagana rice plantation; Lampsar Marigot at Lampsar.

***Gyraulus costulatus* (Krauss, 1844)**

Mali: Tributary of Bafing river, about 63 km north of dam site at Manantali; Senegal River at Moussa Gouya, 25 km southeast of Kayes.

***Biomphalaria pfeifferi* (Krauss, 1844)**

Senegal: Cement-lined canal, Dakar Bango, Saint Louis water supply; Large swamp on the side of Lac de Guiers near pumping station, Dakar water system; Swamp at Pahk village.

Family Lymnaeidae

***Lymnaea natalensis* Krauss, 1848**

Senegal: Cement-lined canal Dakar Bango, Saint Louis water supply; Lampsar Marigot at Makhana; Large swamp on the side of Lac de Guiers, near pumping station, Dakar water system.

Mali: Large swamp at Medina, about 30 km southeast of dam site at Manantali.

Family Ancylidae

***Ferrissia chudeaui* Germain, 1917**

Senegal: Lampsar Marigot at Makhana; Swamp at Pahk village.

Family Thiaridae

***Thiara (Melanoides) tuberculata* (Müller, 1774)**

Senegal: Dakar-Bango, Cement lined canal for

Saint Louis water supply; Lampsar Marigot at Lampsar; Lac de Guiers at several sites on both sides; Irrigation canals, Richard Toll sugar-cane plantation.

Mali: Bafing river at bridge, Mehina.

***Cleopatra bulimoides senegalensis* (Morelet, 1860)**

Senegal: Large swamp under bridge, near Matam, Lampsar Marigot at Savoigne; Irrigation canals, Kassak Sud.

Mali: Tributary of Bafing river, about 63 km north of dam site at Manantali; Bafing river at dam site at Manantali; Senegal river at Moussa Gouya village, 25 km southeast of Kayes and in an irrigation scheme at same village.

Family Viviparidae

***Bellamya unicolor* (Olivier, 1804)**

Senegal: Lac de Guiers at several sites on both sides; Irrigation canals in sugar-cane plantation, Richard Toll.

Mali: Bafing river at bridge at Mehina and at dam site at Manantali.

Family Potamididae

***Tympanotonus fuscatus* (Linnaeus, 1758)**

This brackfish water species was collected near Saint Louis, Senegal.

DISCUSSION

Several bulinid species have been described from material obtained in the Senegal River basin. *Bulinus (Bulinus) senegalensis* is the type species of the genus *Bulinus*. It was described by O. F. Müller in 1781 as *Bulinus senegalensis* and its type locality is Podor, Senegal. It is a new name for "Le Bulin" Adanson, 1757. *Bulinus (Bulinus) guernei* was described by Dautzenberg in 1890 as *Isidora guernei* and its type locality is Tuabo, near Bakel. *Bulinus (Physopsis) jousseaumei* was also described by Dautzenberg (1890) as *Isidora jousseaumei* and its type locality is the Senegal River near Medine. *Bulinus ludoricianus* (Mittre, 1841) was described as *Physa ludoriciana*, from Saint Louis, Senegal. It is probably a synonym of *B. senegalensis*.

Two other species, not originally described from the Senegal River basin, were encountered in certain habitats, and these are: *B. (B.) forskalii* was described by Ehrenberg (1831) as *Isidora forskalii* and its type locality is Damietta, Egypt; *B. (Physopsis) globosus* was described by Morelet (1866) as *Physa globosa* and its type locality is Dande River, Angola.

The genus *Bulinus Müller* is divided into two subgenera: *Bulinus* and *Physopsis*. The morphological features of *Physopsis* are 1) columella is truncate, 2) the shell sculpture consists of spirally arranged rows of small, transverse impressions or nodules. 3) the ventral surface of the kidney has a distinct renal ridge. In the subgenus *Bulinus* the columella is usually straight, although it is sometimes slightly twisted and/or reflexed, but it is never truncate. The shell has pronounced axial sculpture and sometimes ribs, and there is no renal ridge in the animal.

The bulinid species which were collected and studied during this investigation have certain shell and animal characteristic features. These features conformed with those enumerated by Wright (1956) and Mandahl-Barth (1958). It should be noted, however, from our experience that young specimens of *B. (B.) forskalii*, in which the shouldering of the whorls and the costae or ribs are not prominent, may be confused with *B. (B.) senegalensis*. Therefore, examination of adult mature specimens of both species is necessary for a correct identification. Moreover, *B. (Ph.) globosus* and *B. (Ph.) jousseaumei* can be easily confused with each other. This is especially the case when the spire of the shell of *B. (Ph.) globosus* is low and the truncation of the columella is not distinct. Further studies may reveal the synonymy of *B. (Ph.) jousseaumei* with *B. (Ph.) globosus*, the older name.

The above bulinid species in the Senegal River basin are hosts or potential hosts of *Schistosoma haematobium*, *S. bovis* and *Paramphistomum microbothrium*.

As to distribution and ecology of the bulinid species, *B. (B.) guernei* was the most common and was generally found throughout the delta and the lower-middle valley. The only habitat

where *B. (B.) guernei* was not found is the rain-fed laterite pools. Habitats which have relatively long periods of drought showed small populations. *B. (B.) senegalensis* was not collected in the delta or in the Richard Toll area. However, it was consistently found in laterite pools. Similar observations were made in the Gambia by Smithers (1956). In Senegal high densities were recorded for Matam and Ourossoqui, where the sites are dry for extended periods each year, and are rain-fed. Therefore at least few snails must be able to withstand prolonged desiccation. *B. (Ph.) globosus* was found in Mali, Senegal and Mauritania and it seems that it has preference for ponds and flood plains.

Biomphalaria pfeifferi the intermediate host of *Schistosoma mansoni* in West Africa was present only in three locations. It seems to have a preference for swamp conditions, but was also found in a cement-lined canal in Saint Louis.

Two small planorbids *Afrogyrus coretus* and *Gyraulus costulatus* were collected in swampy banks of a lake, from irrigation canals and among vegetation in the Senegal River bank in Mali, and Lampsar Marigot at Lampsar. The two species can be differentiated morphologically by the shell and the verge. The whorls of the shell of *G. costulatus* are rapidly increasing and are regularly costulate. Its adult shell measures 1.2×5.5 mm. The shell of *A. coretus* measures 0.7×3.5 mm, is very flat and the whorls increase slowly. No animals were available for examination.

Lymnaea natalensis is the intermediate host of *Fasciola gigantica* and the only lymnaeid species encountered in the Senegal River basin. Adult shells measure 6×13 mm.

Two thiarid species, *Thiara (Melanoides) tuberculata* and *Cleopatra bulimoides* and a viviparid, *Bellamya unicolor*, have a variety of habitats, such as marigots, rivers, cement-lined canals, lake, and irrigation canals. Especially the thiarids occur in large numbers in these habitats.

The field studies in the Senegal River basin were conducted on three one-month visits to the area: September-October 1977; February-March 1978 and August 1978 and one, 2-week visit in January 1979. The observations made it possible to determine qualitatively the population dynamics of the snail fauna throughout the year.

Water in temporary habitats starts receding about January, and many are dry by the end of February and early March. The majority of the snails die during this drought period, but a few are believed to survive by aestivation. This is rendered possible when the snails become protected in the shade under vegetation; when they fall in deep cracks in the mud, or when they become accidentally buried in the mud. Some of the temporary habitats are cultivated during the drought period and this process is believed to enhance the snails' chance for survival. The rains in the central and middle parts of the Senegal River basin begin early in July, and continue through September. The temporary habitats start filling up, and a gradual build-up of snail colonies is observable by the middle of August. Large colonies are detected by October and they continue as such through December. The period from about the middle of August through January corresponds to the transmission season for human and bovine schistosomiasis, fascioliasis and paramphistomiasis.

With regard to permanent habitats, such as irrigation canals and drains, it was found that the most important determining factor in the fluctuation of snail populations was the silt content of the water. There is a decrease in the snail population density following high silt content, such as during the flood season. Aquatic weeds also decrease in density during this period.

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TELLINA OAHUANA AND *MAUAI* IN HAWAII

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ABSTRACT

Calculation of the height-length ratio of 1000 valves of Tellina oahuana *and* Tellina mauai *shows that the latter is merely an elongated representative of a single population and is considered a synonym of the former. This is one of the most abundant bivalves in the shallow, offshore waters of Hawaii.*

We have dredged specimens of *Tellina* from the R/V *Janthina VII* off Oahu, Molokai, Maui and Hawaii which we had identified as *Tellina oahuana* Dall, Bartsch & Rehder, 1938, and *Tellina mauai* Dall, Bartsch & Rehder, 1938. Dr. Alison Kay, 1979, however, placed *T. mauai* in synonomy of *T. oahuana*. She states that "the species is known only from beachworn valves, a valve dredged by the *Albatross* at a depth of 26 m, and a specimen dredged by the *Pele* off Waikiki." As we have numerous specimens, we felt that a more detailed analysis would be in order.

The only distinguishing features cited by Dall, Bartsch & Rehder is that *T. oahuana* differs from *T. mauai* "in being ovate, instead of elongate-ovate" and that *T. mauai* is "more elongate" than *T. oahuana*. The original description stated that the measurements of the type of *T. oahuana* were: height, 4.1 mm and length, 5.7 mm, which gives a ratio of 71.9. In *T. mauai* the height was 3.7 mm and the length was 6.2 mm giving a ratio of 59.7. We had specimens of approximately these dimensions but in order to ascertain if they were merely parts of a continuum, we measured 1,000 valves of what we considered *T. oahuana* or *T. mauai* using an ocular micrometer in a Bausch and Lomb model 5 stereo-microscope. The ratio of height to length ranged from 60.0 to 86.4 with an average of 70.7. The distribution of the ratios (Table 1) was unimodal and hence we have concluded that all of our specimens belong to the same species, namely *T. oahuana*.

We have dredged *T. oahuana* from 10 to 75 fathoms off Honolulu, Oahu; 25 fathoms off Kahe Pt., Oahu, 27 fathoms off Kokanakaki, Molokai; 16–20 fathoms off Lahaina, Maui; and 30 fathoms off Mahukona, Hawaii. The vast majority of these have been single valves, but living

TABLE 1. *Frequency distribution of the height/length ratio of* Tellina oahuana.

Ratio	*Number of specimens*
60.0–61.9	3
62.0–63.9	3
64.0–65.9	34
66.0–67.9	130
68.0–69.9	205
70.0–71.9	342
72.0–73.9	170
74.0–75.9	82
76.0–77.9	21
78.0–79.9	5
80.0–81.9	4
82.0–83.9	2
84.0–85.9	1
86.0–87.9	1
Total	1,000

specimens have been common. The depth and ive status of the specimens used in this report are shown in Table 2. Twenty-seven of the 38 stations included in this study were in "Pinna Beds" (Burch 1980) where *T. oahuana* is one of he commonest bivalves.

Although the type specimen of *T. mauai* is nore elongate than any of the specimens that ve have dredged, we concur with Dr. Kay's con- lusion that it should be considered a synonym f *T. oahuana*. The type of *T. mauai* was

TABLE 2. *Depths at which* Tellina oahuana *were dredged from Janthina VII.*

Depth (Fathoms)	*Number of Stations*	*Number of specimens*	
		Live	*Dead*
<20	8	27	119
20–29	23	119	837
30–39	2	3	16
40–49	1	10	20
50+	1	2	18
Total	38	161	1,010

dredged by Thaanum in 4–8 fathoms near Lahaina, Mauai, in 1918. This is shallower than we have dredged with the *Janthina VII* but we now plan to dredge at this depth in hopes of finding such specimens.

The specimens used in this study have been deposited in the Division of Mollusks, U.S. National Museum of Natural History at the Smithsonian Institution in Washington, D.C.

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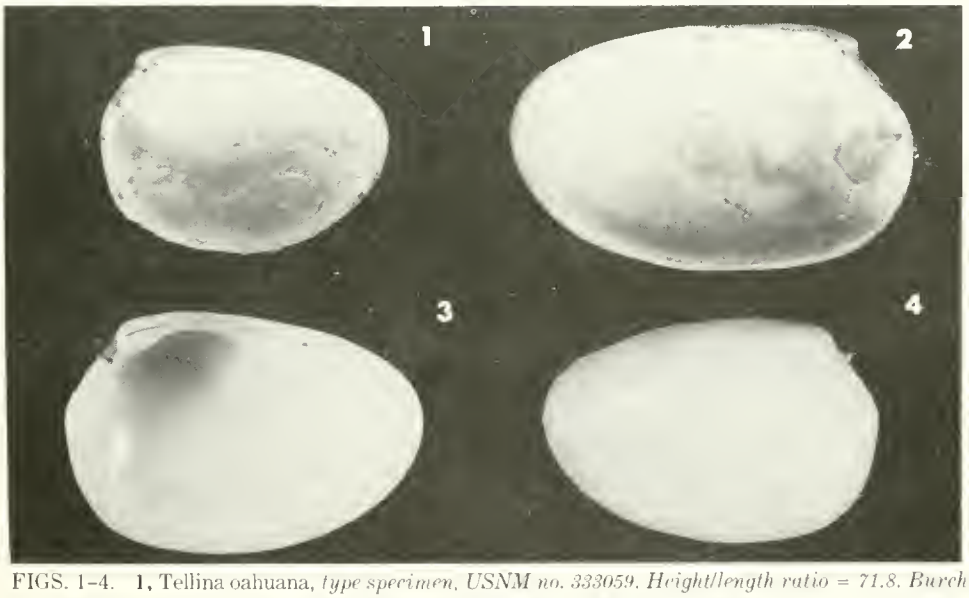
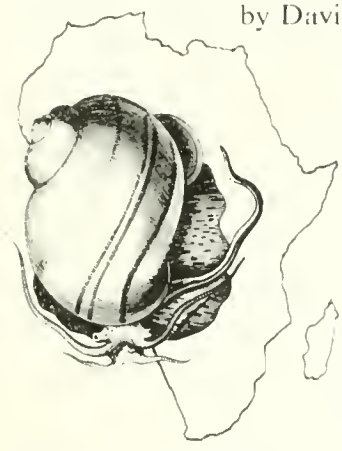


FIGS. 1–4. **1**, Tellina oahuana, *type specimen, USNM no. 333059. Height/length ratio = 71.8. Burch photo A174–5.* **2**, Tellina mauai, *type specimen, USNM no. 337347. Height/length ratio = 59.7. Burch photo A174–8.* **3**, Tellina oahuana, *Burch Station 77080. 22–26 fathoms off Waikiki, Oahu. (interior) Height/length ratio = 69.8. Burch photo N249–12.* **4**, Tellina oahuana, *Burch station 77080. (interior of specimen shown in Fig. 3). Burch photo N249–14.*

Freshwater Snails of Africa and their Medical Importance

by David S. Brown



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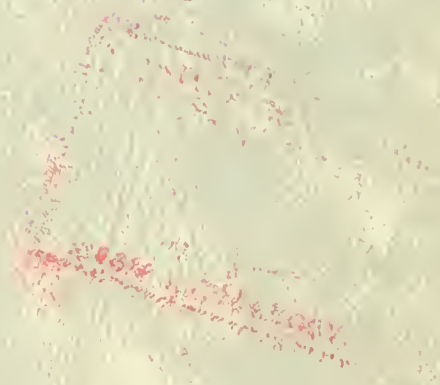

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